Route to:

Return to:

INSTITUTE OF GAS TECHNOLOGY

THE GAS INDUSTRY'S OWN EDUCATIONAL AND RESEARCH FACILITY

CHICAGO 16, ILLINOIS

GAS ABSTRACTS

OCTOBER, 1961

VOLUME 17 NUMBER 10

AFFILIATED WITH

ILLINOIS INSTITUTE OF TECHNOLOGY

CONTENTS

1. **Management**—Gas industry progress, business problems, statistics, government regulation, safety, personnel, education..... 229

2. **Energy Supply and Economics**—Resources, reserves, and competitive applications of the fossil fuels and other sources of energy, including nuclear and solar energy..... 230

3. **Natural Gas and Petroleum Production**—Geology, exploration, drilling, well management, reservoir engineering..... 232

4. **Gas Conditioning and LPG Recovery**—Condensate, dust, CO_2 and sulfur removal, dehydration, odorization, oil fogging, humidification; LPG recovery and refining..... 233

5. **Natural Gas Transmission**—Pipelines, compressors, dispatching, flow regulation, communications, maintenance..... 234

6. **Gas and LPG Storage**—Holders, pressure tanks, underground storage; liquefaction, refrigerated storage..... 235

7. **Manufactured Gas and Chemical Processing**—Gasification of coal, oil; reformed gas; chemical treatment; byproducts; synthesis gas production and conversion; petrochemicals; catalysts, catalyst development..... 237

8. **Gas Distribution**—City utility systems: design, operation, maintenance; weather influence on peak loads and supply; LPG-air mixtures..... 240

9. **Gas Fuel Utilization and Appliances**—Domestic, commercial, industrial; burners; combustion research; air pollution..... 240

10. **Equipment and Instrumentation**—Production and handling equipment, and maintenance; computers; controls; measurement..... 244

11. **Materials of Construction, and Corrosion**—Metals, refractories, plastics; corrosion measurement, prevention..... 244

12. **Analytical Methods and Tests**—Standard and research techniques for gas-making materials, products, processes; instrumental analysis..... 246

13. **Basic Science**—Chemistry, physics and basic engineering related to gas technology; physical properties of gases: phase equilibria, thermodynamics, reaction kinetics, heat and mass transfer, fluid flow..... 247

Services Available to Readers—Photocopies, microfilm, Russian translations, bibliographies and literature searches, *Gas Abstracts on Cards*, back numbers of *Gas Abstracts*.....**Inside Back Cover**

Publications Abstracted for Gas Abstracts.....**Back Cover**

O. P. BRYSCH, Editor P. J. CHATTA, Assistant Editor P. VAN ARSDELL, Assistant Editor

GAS ABSTRACTS is published and distributed monthly by the Institute of Gas Technology, Chicago 16, Illinois. The contents of selected papers and patents are reviewed impartially by the editorial staff and material of potential interest to the Gas Industry is presented.

Subscription rates to nonmembers of the Institute: $18.00 per year to U. S. addresses; $22.00 foreign. Regardless of the month in which it is entered, each subscription starts with the January issue. A gold-stamped fabrikoid binder for the year, and title- and end-pages for that volume, are sent with the January issue. A complete index to the year's issues is mailed as soon after the year's end as it can be prepared, edited and printed.

Copyright 1961 by the Institute of Gas Technology. Printed in the U.S.A.

A microfilm edition of Gas Abstracts can be supplied by University Microfilms, 313 N. First St., Ann Arbor, Michigan.

1. MANAGEMENT

Air Conditioning

Record Year Is About to Begin for Gas Air-Conditioning Sales. W. S. Wepfer. *Public Util. Fortnightly 68,* 528 (1961) Sept. 28 (6 pp.)

All indications point to a record sales year for gas air-conditioning in 1962. Never before in the 30-year history of absorption air-conditioning have conditions been more ripe for the gas industry to "cross the threshold" toward capturing a major share of the year-round cooling and heating market.

Federal Power Commission

Gas Producers and the Courts. W. W. Gatchell. *Public Util. Fortnightly 68,* 499 (1961) Sept. 28 (9 pp.)

An analysis of objections raised by the courts to the use of field prices for producer rates in the area of natural gas regulation. The Federal Power Commission is caught between counterpressures of an increasing backlog of producer cases and judicial insistence on traditional regulatory procedures.

Improving the Effectiveness of FPC Gas Regulations. W. S. Tarver. *Public Util. Fortnightly 68,* 508 (1961) Sept. 28 (4 pp.)

If the natural gas industry is to be regulated, it is in the best interest of those regulated, as well as of the public, that regulation be effective. Ineffective and unsure regulation can only create confusion. Among suggestions are those incorporated in the report prepared by the American Gas Association's Special Committee of Executives on Regulatory Affairs. Those suggestions have largely to do with procedural and organizational matters, the size of the commission, the size of its staff, the size of its appropriations, and so forth. This author had occasion to discuss certain possible improvements in the statutory tools with which the commission works without regard to published criticisms and the proposals for administrative and organizational changes previously mentioned.

Producer Problems Under the Natural Gas Act. J. C. Mason. *Public Util. Fortnightly 68,* 512 (1961) Sept. 28 (7 pp.)

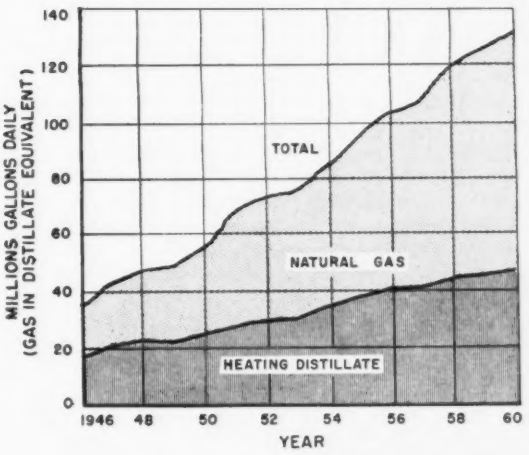
In this discussion of problems in regulation under the Natural Gas Act with respect to interstate operations of producers, all segments of the industry are urged to accept the fact that regulation is here to stay and to assume their respective responsibilities for making regulation work promptly and fairly.

Foreign Activities

French Chemicals Rebound. *Chem. Eng. News 39,* 102 (1961) Oct. 9 (9 pp.)

Having completed its postwar recovery, France is building an aggressive chemical industry. Industrial growth has accelerated sharply in the past five years. The country has found tremendous deposits of oil and natural gas both at home and in its African territories,

Trend in Residential and Commercial Fuel Sales



Adapted from *Natural Gas . . .*
See abstract p. 230.

Algeria and the Sahara. In the past five years, the performance of the French Chemical industry has been outstanding even in resurgent Europe. Even more remarkable is the organic chemical sector. Its production index rose by 58% in 1960 over 1959, despite the fact that it had already risen 32% in 1959 over 1958. France is now competing with Japan for fifth place among the world's chemical producers, following the United States, the Soviet Union, West Germany and Great Britain. France produces about 4.5% of the world's output of chemical products.

Montecatini Develops Acrolein Process. *Chem. Eng. News 39,* 56 (1961) Oct. 9 (2 pp.)

Copper oxide is used as catalyst to oxidize propylene directly to acrolein; process reaches pilot plant stage in Italy. The new Montecatini process is similar to that used by Shell Chemical except that Shell uses a supported catalyst and steam as an inert diluent. Most acrolein on both sides of the Atlantic has been made since World War II by gas phase catalytic condensation of formaldehyde and acetaldehyde. Propylene as a raw material for chemical process had assumed great importance in Europe in the past decade. Petrochemicals have powered much of the recent European chemical progress, and the rash of new steam crackers built there makes propylene readily available at an attractive price.

Oil Rivalry in India. Dr. J. Dubashi. *Petrol. 24,* 333 (1961) Sept. (7 pp.)

Oil in India has become a controversial issue. With the country's sudden surge forward industrially and technically there has necessarily been a need for cheaper power. This problem could be solved if the present search for indigenous supplies, large enough to meet any future needs, is successful. Meanwhile the Government

keeps firm control of the whole industry from exploration to distribution. The author, who was until recently chief of the Energy and Natural Resources Section of the National Council of Applied Economic Research, outlines the struggle between Western and Soviet-aided state-owned oil undertakings.

Some 1959 Gas Issues Exceeded by 20 Per Cent. I. M. Brand. *Nat. Gas Bull. 25,* 16 (1961) June (2 pp.)

For the first time, every utility in Australian gas completed a statistical return, thus enabling the statistics for the calendar year 1960 to give the most accurate information to date. The average increase in gas issued for the Commonwealth was 8.2%.

Gas Industry Expansion

Energy Policy and Competition. J. R. Lichtblau and D. P. Spriggs. Proj. No. 12. Petroleum Industry Research Foundation (1961) (64 pp.)

The present study has been prompted by the debate over the "national fuels policy" the federal government should pursue. The government may continue the traditional approach of encouraging competition, refraining from direct intervention, or formulate a comprehensive policy with specific aims and goals. The energy industries are vitally concerned as well as Congress and the federal Executive. *Energy Policy and Competition,* based on published data, is meant as an introduction to the facts and issues involved, in the role of energy in our economy. In the 1930's about half of the natural gas came from oil wells—compared to 29% in 1959—and the rest came from gas wells tapped during exploration for oil. The first important customers for natural gas were industrial users, attracted by the low price. A sharp rise during the 1940's in the cost of major raw materials used to manufacture gas adversely affected its economic position relative to oil. But the gas utilities were able to tap an alternate supply source in the form of natural gas (whose heat content/cu ft was twice that of manufactured gas). In the residential heating market, there is a large scale national aggressive marketing effort underway for gas heat. This is entirely new in the United States home heating market.

Promotion

American Gas Association in Cooperation with Institutions. Gas Scope. *Institutions 49,* 97 (1961) Oct. (36 pp.)

Features of gas exhibition cooking, research, and development, award winning kitchens, climate control, incinerators, and new appliances are presented.

Gas Has a Big Stake in the Gray Belts. J. H. Collins. *Pub. Util. Fortnightly 68,* 519 (1961) Sept. 28 (9 pp.)

The piece of New York City that was left over was dubbed the "Gray Belt." Similar left-over pieces are to be found in most utility territories, and in fitting them back after redevelopment, electrical, power, telephone, and other companies will build load and also render more service to their communities. To suggest that gas may have advantages may be to speak of war, but these gray belts are changing the basic situation for all utilities. Urban renewal is the market that could yield the load needed to level off its winter peak—and the summer power peak too. With its new spirit of progress, and new pipeline distribution, gas sits pretty, with its three R's—Research, Reserves, and Retailing.

New Horizons for the Gas Industry. L. T. Potter. *Public Util. Fortnightly 68,* 493 (1961) Sept. 28 (6 pp.)

The gas industry today is stronger, larger, and better informed than ever. The function of the American Gas Association in carrying on this consistent program of industrial promotion and information is summed up in the conclusion that today as never before the "gas industry knows where it is and where it must go." AGA indicated its concern in June, 1960, by appointing a committee of top gas distribution and pipeline company executives to review and analyze the regulatory problem and to recommend solutions, called the Special Committee of Executives on Regulatory Affairs—SCERA, for short. AGA now is engaged in a comprehensive job of forward planning for the industry. The activity is known as the Gas Industry Development Program or just "GID".

2. ENERGY SUPPLY AND ECONOMICS

Coal Gasification

Research and Development on Coal. C. M. Cawley. *J. Inst. Fuel. 34,* 375 (1961) Sept. (7 pp.)

This paper seeks to identify the scope for research in the winning, storage, handling, transport, preparation, and utilization of coal. Attention is directed toward the importance of the price of coal. There is much that research and development can usefully do to improve technology, but it may only be economically justifiable to do it if the price of coal shows a sufficient advantage over that of oil. Coal utilization is considered in relation to the making of gas, chemicals, and metallurgical coke, and to its direct use as a fuel. There is continuing scope for research and development in all these fields, but the conclusion is reached that work in the future on coal combustion is likely to be specially fruitful. Particular attention is therefore given to work on coal as a fuel.

Competitive Fuels

Natural Gas Closing in on Heating Oil's Last Big United States Market. *Oil Gas J. 59,* 98 (1961) Sept. 25 (2 pp.)

If present trends continue, natural gas will surpass heating oil in the Atlantic Coast markets in a few years. During the past 10 years, however, demand for distillates in the coastal region doubled with natural gas demand nearly quadrupled. This left an edge for distillates in 1960 of only 3 to 2, or about 30.2 million gallons daily for distillate compared with the equivalent of 20.9 million gallons for natural gas. Natural gas also made spectacular gains in other districts—especially in the Middle West, the nation's greatest fuel market. Gas enjoyed a 155% growth in demand there compared with a 100% growth for distillates.

Energy Sources

Heat Pumps: How Do They Operate? What Really Are the Drawbacks? W. A. Scully. *Gas Heat and Comfort Cooling 12,* 29 (1961) Oct. (5 pp.)

Since the heat pump is basically a refrigeration system, a refrigeration cycle is reviewed. A refrigeration cycle is defined as a heat machine that receives heat at one level of temperature and disposes of it at a higher temperature. Fundamentally, the heat pump is a form of electric heating and its economic status in the field of heating is determined by the prevailing power rate. At the present time, the power rate in most parts of the country is such that electric heating is much more costly.

MHD—Magnetohydrodynamics. M. S. Sodha. *Ind. Research No. 14,* 56 (1961) Oct. (4 pp.)

Only recently have MHD power generation experiments been successful. Gaseous magnetohydrodynamic generators have three main advantages over conventional turbogenerators. Efficiency, the main attraction in MHD power generation, results from fuller utilization of high temperatures attainable in the combustion process. Combustion gases (properly mixed with easily ionized materials) enter the magnetohydrodynamic generator, where power is extracted from the gas and its enthalpy (heat capacity + kinetic energy) is reduced. Versatility of MHD generators, from a systems point of view, is claimed because both stationary and auxiliary power applications are possible. Simplicity, results from the absence of rotating machinery in MHD generators, and easier maintenance and flexibility in design and operation are possible.

Plasma Engine Developed by Republic Aviation for Auxiliary Use in Spacecraft. *Business Week, No. 1674,* 73 (1961) Sept. 30.

Republic Aviation has developed a light compact electric space engine that will be tested next year. This engine uses electricity from batteries or solar cells to create a powerful magnetic field around a chamber of nitrogen or some other inert gas. The "pinch" effect of magnetism turns the gas into a plasma that can be directed to do the work of a jet. Such a jet is tiny in volume, but it can do work where there is little resistance, as in the near-vacuum of space, and its efficiency in using its fuel is so great it can operate for years, with freedom from mechanical troubles. Even though ejected gases have been measured at around 200,000°F the magnetic pinching of the plasma down the center of the chamber keeps the cylinder's wall relatively cool (200 to 300°F). So there is practically no wear and tear on the engine through heat, and none from moving parts.

Solar Machines in Space. H. Oman. *Ind. Research No. 14,* 63 (1961) Oct. (7 pp.)

Announcements and technical papers following the invention of the silicon solar cell in 1954 at Bell Laboratories discussed applications such as powering remote telephone stations, providing emergency power in life boats, charging flashlight batteries, and eventually supplying the energy needs of mankind. But scarcely a word was said about the use of solar cells for space vehicle power supplies then or until 1957. A new solar cell, 10 to 100 times more resistant to damage from radiation in space has been developed by Signal Corps scientists and undergoing radiation tests at RCA Laboratories.

Thermionics. J. A. Welsh and J. Kaye. *Ind. Research No. 14,* 51 (1961) Oct. (5 pp.)

Thermionic generators have progressed to an advanced stage in 1961, complete with intense competition. The first application of thermionic generators most likely will be military, with nuclear radiation as a heat source, or in space power systems using radiation from the sun. These limitations are imposed by the very high temperature heat source required by the generators. Only a few costly high temperature materials are available for construction, restricting applications to those where cost is not the first consideration. Broad application of thermionic converters as power suppliers must await a breakthrough in high-temperature technology.

The Traveling-Wave Pump. E. E. Covert and C. W. Haldeman. *ARS J. 31,* 1252 (1961) Sept. (9 pp.)

An ionized gas can be accelerated by a moving magnetic field. This principle has been used to produce an electrodeless a-c accelerator called a "traveling wave pump". High gas velocities are obtainable in this way. The operating principle of the "traveling wave pump" is discussed. A prototype experimental facility of this type is described. The possible application to electrodeless power generation is also briefly mentioned.

Thermoelectricity. W. B. Green. *Ind. Research No. 14,* 28 (1961) Oct. (7 pp.)

When two materials are joined and heated, a potential difference results—the phenomenon is the basis for new heating, cooling, and power generation. The principle underlying thermoelectricity is not new, but rather has been given new impetus as investigators gain new insights into thermoelectric effects. The potential difference increases as the temperature of the joint increases, as compared to portions of the materials away from the joint. Under development for instance, are small volume refrigerators for use in autos, boats, and planes, but also devices for cooling electronic components, photomultipliers, and light fixtures; and large volume refrigerators for submarine air conditioning. This is but a partial list of the many applications for thermoelectricity.

Fuel Cells

Fuel Cell in Space. H. A. Liebhafsky and W. T. Grubb, Jr. *ARS J. 31,* 1183 (1961) Sept. (8 pp.)

The outlook for the fuel cell in space seems to be this: If the severe reactivity and invariance requirements can be met even moderately well, the device should prove useful on missions too long for primary batteries. It should also prove an attractive alternative to secondary batteries, on extremely long missions in which the fuel can be regenerated by using another form of energy, preferably that of the sun. Intensive research on all

kinds of fuel cells can therefore be justified also on the basis of space age needs. It seems unnecessary to add that this resume of the fuel cell in space was made primarily from the point of view of research and does not pretend to treat the many important engineering problems involved.

Fuel Cell Operations. T. A. Ciarlariello. (assigned to M.S.A. Research Corp.) U.S. 2,997,517 (1961) Aug. 22.

A fuel cell is claimed comprising two spaced electrodes and an electrolyte. The electrodes are both fluids (hydrogen and molten lithium) and the electrolyte is more dense than either fluid (lithium chloride and fluoride) because of tangential injection and centrifugal flow through the cell. The cell body is formed by the intersecting sidewalls of two vertical cylinders, permitting electrolyte flow, but barring flow or contact of electrode material.

Sun Oil and Electric Storage Battery Pair Up for Work on Fuel Cells. *Business Week No. 1674,* 73 (1961) Sept. 30.

An agreement was signed to exchange research information and to cooperate in the development of fuel cells. Both companies have been working on developments related to fuel cells for a number of years. Fuel cells unlike conventional electric batteries, convert the heat produced in a chemical reaction directly into electricity. In recent years, dozens of leading companies here and abroad have carried on intensive research in the field.

The Present Status of Fuel Cells and Batteries. G. S. Lozier. *Eng. Digest 22,* 74 (1961) Sept. (6 pp.)

This paper discusses the present state of development of fuel cells and batteries as energy sources and energy storage devices. The various types described are evaluated from a consideration of the energy content of the reactant materials and the basic methods of handling them in electrochemical cells. Regenerative electrochemical cells are also discussed, with emphasis on space applications.

Fuel Cells. E. A. De Zubay and E. B. Shultz, Jr. *Ind. Research, No. 14,* 19 (1961) Oct. (8 pp.)

With more than 60 known industrial and government projects of some importance underway, fuel cells today are the most diversified of all energy conversion concepts under investigation. The automotive, electronic, battery, gas, petroleum, and electric industries all are actively developing fuel cells to suit the many special requirements of civilian, military, and space applications. The Institute of Gas Technology, Chicago, under American Gas Association sponsorship, currently is developing high temperature fuel cells to use natural gas. In most parts of the country, a unit of energy in the form of gas costs the residential consumer only 1/6 to 1/10 as much as a unit of energy in the form of electricity. If natural gas cells can be perfected, basic costs would be reduced significantly. The low cost of transporting and distributing energy as gas to consumers' homes could provide the convenience and versatility of a single source of heat and electrical energy.

3. NATURAL GAS AND PETROLEUM PRODUCTION

Drilling

Engineered Hydraulic Programs Reduce California Drilling Costs. B. M. Bumgardner. *World Oil 153,* 126 (1961) Oct. (6 pp.)

Improved drilling practices and techniques have cut drilling costs. Effective aids in cutting costs were: more efficient hydraulics and a better understanding of their use; use of lower annular velocities; limiting of maximum pump pressure to 2,500 psi, in most cases; increased weight on the bit so as to increase penetration rates, although crooked hole conditions dictate caution in utilization of this practice; more efficient use of rig horsepower resulting from the minimum circulation rates believed necessary for adequate annular velocity; maintenance of an accumulative drilling cost curve so a clear and accurate cost/ft figure is made available.

How to Predict Diamond Bit Drilling Costs. R. I. Peters. *World Oil 153,* 122 (1961) Oct. (4 pp.)

Inherent differences existing between diamond bit and rock bit performance, in comparable formations, make direct comparisons between these two types of bits extremely inaccurate unless total hole costs are considered. To help define and predict diamond drilling costs, in terms that can be compared with drilling costs by other methods, a mathematical technique has been developed which permits comparing diamond bit costs with rock bit costs. The method involving simple formulas and curves is based on total hole costs consisting of: actual rig costs in dollars/hr, net cost of bit, and round trip time expressed in hr.

Sanity or Suicide. A. G. Slaydon and M. E. Surratt. *Drilling 22,* 56 (1961) Sept. (6 pp.)

This article presents the grim financial picture of the drilling industry whose current practices threaten economic self destruction. It is dollars-and-cents proof of the urgent need for joint contractor-operator-supplier efforts to restore some sort of sensible balance in the contract drilling business. An economic yardstick is presented whereby the contractor can measure his performance against a "norm" for the industry, and this can be used also in the formulation of financial policies and in the analysis of specific company problems.

Threadless Drill Pipe Tool Joint: A Progress Report. J. E. Kastrop. *Petrol. Eng. 33,* 54 (1961) Oct. (4 pp.)

The first major change in drill pipe joints from the standard threaded connection and conventional methods of making up and breaking out such a joint, was first announced about 3 years ago. This joint makes possible simple and quick disengagement of drill pipe from casing assembly after cementing the pipe, as well as reengagement for subsequent drilling and testing operations. Latest prototype of the new threadless drill pipe tool joint uses the identical principle of operation as the existing model of the right hand torque releasing safety joint. Primary difference between the safety joint

and the drill pipe tool joint version is the method of releasing the joint.

Piping

Non-Destructive Testing of Welded Tubing. W. A. Black. *Petrol 24,* 348 (1961) Sept. (5 pp.)

This article reviews various types of nondestructive testing that has been carried out by Republic Steel Corp. of Cleveland, Ohio, on resistance-welded tubing. All types of tests have been examined—hydrostatic, radiography, ultrasonics, magnetic particle, and electromagnetic induction (Farrowtest)—and each has been found to have advantages and limitations.

Reservoir Engineering

Pressure Drop in a Composite Reservoir. T. L. Loucks and E. T. Guerrero. *J. Soc. Petrol. Eng. 1,* 170 (1961) Sept. (7 pp.)

Pressure drop characteristics in a system composed of 2 adjacent concentric regions of different permeability were studied. The differential equations for continuity of mass flow in the 2 regions were solved using the Laplace transformation and the necessary boundary conditions to give the pressure distribution in the composite reservoir, the resulting equation for the pressure drop at the inner boundary was evaluated for a variety of composite reservoirs and compared with the results for a uniform reservoir. From this study it was found that under certain conditions the permeability in both zones, as well as the size of the inner zone, can be determined from the pressure drop curve.

The Calculated Performance of Solution-Gas-Drive Reservoirs. J. S. Levine and M. Prats. *J. Soc. Petrol. Eng. 1,* 142 (1961) Sept. (11 pp.)

Several methods are available for calculating the performance of solution-gas-drive reservoirs from the PVT properties of the oil and from the relative permeability and other properties of the formation. These methods require a number of simplifying assumptions. The present method of computation has made use of a high-speed computer to solve simultaneously the nonlinear partial differential equations that describe 2 phase flow by solution-gas drive in order to calculate the performance of a reservoir. Some of the results obtained by the nonlinear partial differential equation solution are compared with those obtained with an approximate method, which has been called the semisteady-state solution.

Well Practice

New Completion Will Cut Workover Costs. R. H. Adolph and J. B. Cobb. *World Oil 153,* 150 (1961) Oct. (5 pp.)

Advantages of the parallel completion method are: prevention of communication between zones resulting from blast holes in tubing strings; provision of positive segregation of producing intervals—each string can be worked over individually; reduction of workover costs since work on one zone is equivalent to a single well workover; elimination of difficulties encountered in pulling dual parallel strings; and use of externally mounted gas lift valves in each string; with elimination of possible interference between valves while lifting.

New Wellhead Assembly Saves Rig Time. V. D. Stone. *World Oil 153,* 132 (1961) Oct. (5 pp.)

Blowout preventers are installed on the conductor pipe and are not removed until final installation of the tubing hanger and conventional tree.

4. GAS CONDITIONING AND LPG RECOVERY

Dust Removal

Entrainment Separation in Gas Processing. P. W. Sherwood. *Gas J. 307,* 389 (1961) Sept. 27 (2 pp.)

Each entrainment situation calls for a special engineering consideration, and the proper piece of equipment can be selected after careful consideration of all the technical and economic factors involved. In gas processing practice, entrainment separating devices fall into 6 main categories, and this discussion follows several subdivisions.

Gas Cleaning

Design and Operating Tips for Gas Scrubbing Systems. G. D. Hall and L. D. Polderman. *Can. Gas J. 54,* 40 (1961) Sept. (7 pp.)

There are two types of plants commonly utilizing the ethanolamines as acid gas absorbents. The Girbitol process employs a relatively dilute solution of either monoethanolamine or diethanolamine. The Fluor process generally uses a mixture of methyl ethyl amine and diethylene glycol with approximate 5% water. While the latter process provides simultaneous dehydration and acid gas removal, the dew point depressions normally obtained are 50°F, or less, thus limiting its application to areas having moderate winter climates. Despite their fairly long history of use, operating problems are still encountered including—foaming, degradation of amines, sludge accumulations, failure to sweeten effluent gas, and corrosion.

Hydrates

Hydrates in Systems Containing Methane, Ethylene, Propylene, and Water. L. E. Snell, F. D. Otto, and D. B. Robinson. *A.I.Ch.E. J. 7,* 482 (1961) Sept. (4 pp.)

The initial hydrate forming conditions for the systems ethylene-water and methane-ethylene-water were investigated to about 9,000 psia. It was found that at a given pressure, the initial hydrate forming temperature for mixtures containing greater than about 65 mole% ethylene was higher than the initial formation temperature for either methane or ethylene. Solid vapor equilibrium ratios were calculated for the ethylene hydrate. A comparison between experimental and predicted hydrate forming conditions for the system methane-ethylene-propylene-water was made for several different mixtures of these gases. This comparison

showed that the predicted hydrate forming temperature was slightly higher than the experimental at a given pressure.

Hydrocarbon Removal

Method for Purifying Hydrogen Contaminated With Methane. J. Huebler (assigned to Midland-Ross Corp.) U.S. 2,998,303 (1961) Aug. 29.

A purification process is claimed for hydrogen to be used as an atmosphere for heat treatment of metals. Gas contaminants, usually methane and CO formed from the carbon in steel are removed from the hydrogen stream by mixing 1 mole with 9 moles of steam, heating the gas to 900°F and passing it through a catalyst tower containing ruthenium and rhodium catalysts. The carbon dioxide so formed is removed by scrubbing and the hydrogen, dried by desicants, is recirculated.

Hydrogen Sulfide Removal

A Method of Selectively Separating Hydrogen Sulphide from Gases Containing Hydrogen Sulphide and Carbon Dioxide. H. M. Guinot (assigned to Societe pour l'Equipment des Industries, Chimiques-S.P.E.I.C.H.I.M.-Reunion des Anciens Etablissements Barbet, Egrot, & Grange, Pingris & Mollet Fontaine) U. S. 2,994,578 Aug. 1, 1961.

A process for selective separation of hydrogen sulfide from gases also containing CO_2 consists of scrubbing the gas with a solution of 5 g mol/liter of dipotassium hydrogen phosphate, and adjusting flow-rates to absorb all H_2S. Because of its slow rate of absorption, CO_2 is not removed. The fouled solution is put under vacuum and strongly agitated to liberate the H_2S.

Purification

Method and Devices for Separating Components from a Gas and/or Vapor Mixture. E. Hellingman, C. J. M. van der Laan, and L. Roozendaal. (assigned to North American Philips Co., Inc.) U. S. 2,999,364 (1961) Sept. 12.

A method is claimed for separating condensable components from a gas by cooling. A metal gauze wall is cooled by a plate heat exchanger and the raw gas passed through a layer of snow formed on the gauze. The porous snow-layer traps water, and with more cooling, traps CO_2. A trough below removes the warmed liquid from the layer during regeneration.

Sulfur

Production of Sulfur. P. Urban and W. K. T. Gleim (assigned to Universal Oil Products Co.) U. S. 2,998,-304 (1961) Aug. 29.

A process for the production of sulfur is claimed in which hydrogen sulfide is scrubbed with a solution of sulfur dioxide in a water-saturated hydrocarbon distillate. An aralkyl sulfonate detergent is added to the solvent and a small amount of free water may be present. The sulfur crystallizes in the water layer, which is separated and treated. Water and solvent are cooled and recycled.

The Chemistry of Sulphur in Coal. P. H. Given and W. F. Wyss. *B.C.U.R.A. Monthly Bull. 25,* Rev. No. 204, 165 (1961) May (15 pp.)

The presence of sulfur in fuels has an importance out of proportion to the concentration, which is normally quite small: the products of its combustion have deleterious effects on the metal components of combustion systems and on the quality of products such as steel and glass with which combustion gases may come in contact; air pollution may be caused when the flue gases are finally discharged. Moreover sulfates play a leading role in the formation of many boiler deposits. The review summarizes the chemistry of the types of compounds in which sulfur may occur in bituminous coal. Washeries can remove the inorganic sulfur only and that not completely—carbonization is only a little more effective.

5. NATURAL GAS TRANSMISSION

Compressor Stations

Aviation-Type Turbine Delivers for Columbia. S. Orlofsky. *Oil Gas J. 59,* 168 (1961) Sept. 25 (4 pp.)

The Columbia Gas System has operated a 10,500-hp jet gas turbine driving a 2-stage centrifugal compressor at its Clementsville, Ky., station since October 31, 1960. Projected yearly operating costs are $21.70 per installed horsepower, comparable to 4-cycle engine-driven centrifugal stations. A single building acts mainly as a simple covering for equipment; the compressor is installed directly into the pipe line, on a 4 to 5 acre site as compared to 20 to 40. The equipment is unattended and is remotely controlled.

Updating those Older Pipeline Stations. 2. Natural-Gas Pipelines. H. C. Bozeman. *Oil Gas J. 59,* 129 (1961) Sept. 25 (12 pp.)

Gas pipelines have been starting modernization programs with caution. They try several approaches before making a final choice. Initially one station or compressor is modernized. Then more stations or compressors are updated after the equipment proves its value. The reason for the insistence on reliability is down time's high cost. However, a small percentage increase will pay modernization cost many times over.

Coatings

Report of Task Group on Internal Pipe Coatings. J. H. Davis. *Pipeline News 23,* (1961) Sept. (4 pp.)

The following, in the order of the relative importance, have been listed in the report of A.G.A.'s Pipeline Research Committee's Project NB-14, as the physical properties required when the "joint-at-a-time" method of internal coating is used: 1) adhesion rating at room temperature, 2) impact resistance rating at room temperature, 3) abrasion resistance rating at room temperature, 4) flexibility rating at room temperature, 5) gas blistering derating, and 6) welding resistance derating.

Pipeline Construction

Apparatus for Lining Pipelines. F. M. Matheny (assigned to American Pipe and Construction Co.) U. S.

2,996,085. Aug. 15, 1961.

An apparatus is claimed for winding helically coiled wire reinforcement inside a gas pipe. This comprises a wheeled carriage to be advanced through the pipe, and a wire-feed head mounted for rotation about an axis coincident with pipe axes. Wire feed means are provided to advance the wire radially against the inner pipe wall. A dynamic brake on the feed head prevents it from rotating when wire is forced against the wall.

Records Topple in Building '61's Biggest Pipeline Project. *Oil Gas J. 59,* 154 (1961) Sept. 25 (8 pp.)

Spreads in Alberta have broken records for laying such large pipe. In British Columbia the 80-ft joints have been aggressively laid over alpine mountains where difficulties seemed prohibitive. The whole Alberta-California project, of which this work is a part, has demonstrated, on the largest scale, what can be accomplished by extensive use of double joints. Results so far indicate that project costs are well within the construction budget.

Western Backs up Speed Records. W. Quarles. *Pipeline News 23,* 39 (1961) Sept. (4 pp.)

Pipeline speed records are a temporary possession, waiting only for a combination of favorable circumstances before they are broken. However, this 2.96-mile-per-day average, set on 36-inch pipe on Pacific Gas Transmission Co.'s project, in choppy and rugged terrain, is likely to stand for some time.

Winter No Longer Stops Pipe Line Construction. *World Petrol 32,* 48 (1961) Oct. (2 pp.)

Stimulated by the necessity of getting the entire foothills division of the Alberta Gas Trunk Line Co. Ltd. into the ground by November 1, although the construction contracts were awarded only late last fall, contractors have hustled up new techniques, and have experimented with winter operations, to prove conclusively that seasonal interruptions for cold weather and even for wet periods can be practically eliminated.

Pipelines—By Product

What are the Chances of a New By-Product Pipeline? I. Wilson. *Can. Gas J. 54,* 46 (1961) Sept. (6 pp.)

Last year a petro-chemical pipeline plan was quashed but a new look at the problem must be taken. Mounting exports and increasing home consumption continue to spark Canada's natural gas processing industry. The rapidly approaching November 1st date set for deliveries of gas by the Alberta-California Trunk Line will add approximately 900 MMCF/D to the processing capacity of the industry. Propane is presently outstripping the demand, but the balance between production and marketing is not large. Butane is being produced in amounts far in excess of any possible demands in the various plant locations. Sulfur is also being overproduced having risen from 8,391 short tons per year to 450,187 in 1960. During the past 8 years processing plants have produced more than 1 million tons of sulfur, only about half has been marketed. Stockpiles are being pyramided at a rate of nearly 2,000 tons daily. Four pages of tables list 32 new installations and their location.

Piping

Columbium Steel may be Answer to Need for Improved, Safer Line Pipe. A. G. Barkow. *Oil Gas J. 59,* 143 (1961) Sept. 25 (8 pp.)

As a steel additive, columbium adds appreciable to tensile and yield strengths. It also reduces hardenability, a valuable adjunct to welding. And it has very little effect on the ductility as measured by elongation and reduction of area.

Cyclic Loads on Branch Connections. G. M. McClure and T. J. Atterbury. *Pipeline News 23,* 30 (1961) Sept. (6 pp.)

During the past 2 years another phase of this branch connection work was started—investigating behavior of branch connections under cyclic loads. This companion program on cyclic loads was started because of difficulties with fatigue cracks in piping around reciprocating compressor stations.

6. GAS AND LPG STORAGE

Liquefaction

Natural Gas Liquefaction Cycle. S. E. Tung. (assigned to Conch International Methane Ltd.) U. S. 2,996,891 (1961) Aug. 22.

A method is claimed for liquefying and purifying natural gas, containing essentially methane, but also heavier hydrocarbons and acid gas. This comprises lowering the stream temperature (at 720 psia) but maintaining pressure above maximum of univariant vapor-liquid-solid equilibrium curve. Then the heavy hydrocarbons which liquefy are separated, and gas temperature is further reduced to partially liquefy the main stream, and to cause solidification of acid gases (CO_2 and H_2S). Alternate scrubbers may be used for the removal of the latter solids.

Liquefied Gas Holders

Insulated Tank for Liquefied Hydrocarbons and the Like with Loose Membranous Lining Therefore. W. L. Morrison. (assigned to Conch International Methane, Ltd.) U. S. 2,994,452 (1961) Aug. 1.

A storage tank for liquefied hydrocarbons is described which avoids wetting the insulation. The usual outer shell is provided, capable of supporting the liquid load, and is lined with thick balsa wood insulation. An inner container of flexible glass fiber cloth impregnated with plastic is supported by roof and wall clamps and contains the cold liquid.

Liquefied Gases

Bowing of Cryogenic Pipeline. W. G. Flieder, J. C. Loria, and W. J. Smith. *Am. Soc. Mech. Eng. Trans.; J. Appl. Mech. 28,* 409 (1961) Sept. (8 pp.)

The design of propellant loading systems for present day missiles involves the design of pipelines that can carry cryogenic fluids and requires an additional consideration beyond the conventional analysis for flexibility and

deadweight. Because of varying flow conditions and boil-off, these cryogenic lines experience varying fill levels and concomitant temperature gradients which cause these lines to bow; that is, to assume a uniform curvature of circular arc. If constrained, the thermal stress distributions which are generated by the temperature gradients will have superposed on them additional stresses, which result from the action of the support constraints. This combination of stresses may be critical and/or the loads on the supports may be excessive. The analysis given investigates these bowing effects, thermal stresses, and indicates the support problems entailed.

Multiple Liquid Phases in a Natural-Gas System. L. Stroud, W. E. DeVaney, and J. E. Miller. *J. Soc. Petrol. Eng. 1,* 137 (1961) Sept. (5 pp.)

During a recent phase study of a natural gas, two stable equilibrium liquid phases were observed at temperatures below −200°F and pressures above 200 psi. The published literature is reviewed on the occurrence of multiple equilibrium liquid phases of the liquefied natural gas at 5 experimental conditions. In addition, data for 30 conditions of two-phase equilibria are included.

Refrigerated Storage

Insulated Cryogenic Storage Tank. I. V. LaFave and I. L. Wissmiller. (assigned to Chicago Bridge & Iron Co.) U. S. 2,999,366 (1961) Sept. 12.

An insulated cryogenic storage tank for liquefied gases is comprised of an inner storage vessel with particular light weight insulating material in the annular space. To avoid compaction, caking, and channeling in the insulation, a slow flow of gas is injected at the base of the outer housing of sufficient velocity to fluidize the insulating powder in a dense phase, and this fluidization is maintained during periods of changing tank wall temperatures.

Underground Storage

Investigations Into Gas Storage Underground. C. H. Leach. *Gas World 156,* 370 (1961) Sept. 23.

Formations of "green sand"—strata that are porous and permeable have been found at Winchester between 600 and 1,000 ft down and hold promise, if nothing goes wrong, of making it possible to store underground something like 10 thousand million cubic feet of gas.

Making Underground Storage Caverns. P. G. Carpenter. (assigned to Phillips Petroleum Corp.) U. S. 2,994,200 (1961) Aug. 1.

An improved method of making an underground storage cavern for liquefied petroleum gas is claimed. Usual casing is set by cement in upper or roof layer of salt formation, water is first circulated through the casing, dissolving roof salt in an annular recess pattern around the foot of the casing. Then liquefied petroleum gas is pumped down to fill the roof recess and water circulation is continued, holding the liquefied petroleum gas between the water and the roof, until a sufficient large cavity is washed out. Salt solution is then displaced through the lowered string of pipe by the liquefied petroleum gas.

The Thermodynamics of Frost Damage to Porous Solids. D. H. Everett. *Trans. Faraday Soc. 57,* 1541 (1961) Sept. (11 pp.)

The thermodynamics of the formation of "ice lenses" in porous material is discussed in relation to experience and experiment on the damage caused by frost to roads and building materials. Qualitatively the theory is in accordance with known facts, but a precise quantitative correlation is difficult partly because of the complexity of porous materials and partly from lack of a reliable value for the surface tension of ice. Studies of ice lens formation using simple apparatus might, however, provide a method of determining the surface tension of ice.

Thermal Conductivity of Porous Media. I. Unconsolidated Sands. W. Woodside and J. H. Messmer. *J. Appl. Phys. 32,* 1688 (1961) Sept. (12 pp.)

The problem of determining the effective thermal conductivity of a 2-phase system, given the conductivities and volume fractions of the components, is examined. Equations are described which have been proposed as solutions to this problem, including those of Maxwell, de Vries, and Kunii and Smith, the weighted geometric mean equation, and an equation based on a 3-element resistor model found applicable to the analogous electrical conductivity problem. Experimental results are presented for 5 consolidated samples: 3 quartz sand packs, a glass bead pack, and a lead shot pack. The method of conductivity measurement using the transient line heat source (thermal conductivity probe) is described.

Thermal Conductivity of Porous Media. II. Consolidated Rocks. W. Woodside and J. H. Messmer. *J. Appl. Phys. 32,* 1699 (1961) Sept. (7 pp.)

Measurements have been made of the effective thermal conductivity of porous sandstones. The method is based on the transient heating effect resulting from use of a line heat source. Data are presented for 6 sandstones ranging in porosity from 3 to 59% and show the variation of thermal conductivity with porosity, the conductivity of the saturating fluid, the pressure of the gas filling the porespace, and overburden pressure. The results are compared with those previously obtained for unconsolidated sands. All samples, except one, exhibited a lower thermal conductivity when saturated with a gas at atmospheric pressure than when saturated with a liquid of the same conductivity as the gas.

Underground Storage of Hydrocarbons. G. M. Closs and P. F. Dougherty. (assigned to Sun Oil Co.) U. S. 2,991,-624 (1961) July 11.

An improvement in C_2—C_4 hydrocarbon storage in underground caverns is claimed, which specifies a method of reducing leakage. The hydrocarbon is saturated with water prior to injection into the cavern, then is introduced under pressure. Any leakage through the formation to a zone of lower pressure results in vaporization of hydrocarbon and formation of solid hydrocarbon hydrate which plugs the leakage channels.

Search for Lurgi and Storage Sites. *Gas Times 95,* 36 (1961)

The work for exploration on underground storage sites is sponsored by the Gas Council in various parts of the country. Two drilling teams are at work in the Cotswolds, and work has been completed at Chipping Norton.

7. MANUFACTURED GAS AND CHEMICAL PROCESSING

Carbon Disulfide

The Production and Uses of Carbon Disulphide. W. J. Bushell. *Chem. & Ind. 1465* (1961) Sept. 16 (6 pp.)

Carbon disulfide is an essential raw material for the manufacture of viscose for both fiber and film production, and this industry uses a high percentage of the total. An important basic chemical, the annual production of carbon disulfide in this country varies with the buoyancy of the viscose industry, but amounts to about 75,000 tons/yr, most of which is produced in one factory. The retort process is at present the most important one in the United Kingdom measured in terms of total output. The principle of the retort process is quite simple. Sulfur and charcoal are brought to reaction temperature in a cast-iron retort, and the reaction products consisting of carbon disulfide, unconverted sulfur, hydrogen sulfide, carbon oxysulfide, and inert gases are passed through a condensation section. The crude carbon disulfide is distilled and the other sulfur containing products reconverted for re-use.

Carbon Monoxide

Method for Continuous Manufacture of Carbon Monoxide. A. L. Mossman. (assigned to The Matheson Co. Inc.) U. S. 2,996,359 (1961) Aug. 15.

A process is claimed for continuous production of pure carbon monoxide. This comprises preheating a continuous stream of concentrated sulfuric acid (98%) to about 100°C, delivering this stream and a continuous stream of formic acid (90%) to the top of a reactor, mixing and passing the mixture downward through a ceramic packed reactor zone steam heated to 120—130°C. The carbon monoxide is drawn off from the top of the reactor and washed to remove acids.

Catalysts

Adsorption of Nitrogen and Hydrogen on a Promoted Iron Catalyst. M. V. C. Sastri and H. Srikant. *J. Sci. Industr. Res. (India) 20D* No. 9, 321 (1961) Sept. (9 pp.)

A study has been made of the adsorption of nitrogen and hydrogen at elevated pressures up to 50 atmospheres and at 7 temperatures between 97° and 400°C on a commercial ammonia synthesis catalyst. Absorption measurements have been made with pure gases as well as their 1:3 synthesis mixture, employing a direct volumetric technique. For characterization of the surface of the catalyst, low temperature adsorption of nitrogen, carbon monoxide, and carbon dioxide has been studied.

Catalytic Oxidation of Methane. R. B. Anderson, K. C. Stein, J. J. Feenan, and L. J. E. Hofer. *Ind. Eng. Chem. 53,* 809 (1961) Oct. (4 pp.)

The activity of catalysts for the total oxidation of methane was determined as a part of a program for developing devices to monitor methane concentration in coal mine atmospheres. For this purpose, a number of catalysts were tested in a microcatalytic reactor. Thirty catalysts were tested for their effectiveness in oxidizing methane. The present results from the microcatalytic reactor were consistent with available published data. Yant and Hawk examined pure metal oxides and found that Co_3O_4 was the most effective.

Coal

Dehydrogenation of Coals and Its Relation to Coal Structure. P. H. Given. *Fuel 40,* 427 (1961) Sept. (5 pp.)

Recent researches bearing directly or indirectly on the presence of hydroaromatic structures in coal are reviewed. It is shown that these in some measure support the model structure previously proposed, but also make some modification necessary; in particular, although it is confirmed that the aromatic nuclei in coals are linked through hydroaromatic rings, the latter are more likely to be of 1,2- than 1,4-cyclohexadiene type.

Coal Carbonization

Rexco Smokeless Fuel and Byproducts. *Coke and Gas 23,* 352 (1961) Sept. (7 pp.)

In 1955 a new site was laid out for further annual production of over 200,000 tons of Rexco. Seven retorts were commissioned in 1957 and a second bench of seven put to work in 1959. In the Rexco process the heat is provided directly into the body of the coal charge by hot gases which are drawn down through the retort. The retorts, each holding about 35 tons of coal are larger than coke ovens and to hold this weight of coal a cylindrical brick lined steel vessel 25 ft high and 10 ft in diameter is necessary. There is a charging door at the top to receive the raw coal and a removable grate at the bottom of the vessel for discharging the carbonized Rexco. Connected to each retort is another cylindrical brick-lined vessel—a combustion chamber in which the hot gases are produced to provide the heat for carbonization.

Ethylene

Progress in the Direct Oxidation of Ethylene. V. Gurdjian. *Revista dei Combustilili 15,* 689 (1961) Sept. (16 pp. Italian text.)

The catalytic oxidation of ethylene in the vapor phase to acetaldehyde and acetic acid in the presence of water via ethyl alcohol as an intermediate is described. After some experiments have been carried out in order to verify the possibility of this action, various catalysts containing molybdenum and phosphoric acid have been prepared and it has been found out that they give good yields for the aforementioned two products.

Hydrocarbons

The Formation of Aromatic Hydrocarbons at High Temperatures. Pt. XII. The Pyrolysis of Benzene. G. M. Badger and J. Novotny. *J. Chem. Soc.,* 3400 (1961) Aug. (3 pp.)

Pyrolysis of benzene at 700° has been shown to yield biphenyl as the major product, with significant amounts of p-terphenyl, m-terphenyl, and triphenylene. Fluorene, phenanthrene, anthracene, o-terphenyl, fluoranthene, chrysene, and 3,4-benzofluoranthene were also detected, and methane and ethylene were identified in the exit gases.

Hydrogen

Hydrogen from Oil. H. G. Klinkert. *Chem. & Ind.* 1381 (1961) Sept. 2 (5 pp.)

The production of hydrogen from oil fractions (or more generally hydrocarbons) can be accomplished by various methods, such as: partial oxidation of hydrocarbons, using steam as the oxidant, followed by CO conversion and CO_2 removal; partial oxidation of hydrocarbons using oxygen as the oxidant; and catalytic dehydrogenation of naphtha fractions. Partial oxidation using oxygen has been developed by the Royal Dutch/Shell Group and considerable commercial-scale experience has been gained over the past few years. The limiting factor in the success of the operation is the cost of oxygen. Generally, the use of such a process is attractive only where low cost "tonnage" oxygen is already available, or where the size of the gasification plant is sufficiently large to require an oxygen unit of 100 tons/day or more. To date, the ammonia industry is the only one where such conditions prevail.

Want to Know the Cost of Making Hydrogen? C. W. Ertel. *Petrol. Refiner 40,* 163 (1961) Sept. (4 pp.)

Representative costs for two hydrogen production schemes are discussed. In the size range of 5 to 15 MMSCF/day the cost of hydrogen is from 51.0 to 38.0 cents/MCF for steam reforming at 125 psig (assuming 35 cents/MM Btu for fuel). For the partial oxidation scheme the cost figures are 68.8 to 49.6 cents/MSCF (assuming $2.50/bbl of residual fuel). These cost data are summarized.

Ore Reduction

Technology of Carbonaceous Fuel Additives for Blast Furnaces Expanding Rapidly. *Ind. Heating. 28,* 1652 (1961) Sept. (10 pp.)

A panel discussion by members of the AIME Blast Furnace, Coke Oven, and Raw Materials Committee during the 1961 meeting emphasizes the growing importance of the use of carbonaceous fuel additives for the blast furnace. Little is known of any attempts at fuel injection for blast furnaces during the period from John Dawes' first effort in Europe in 1831 until 1953 when Lone Star Steel experimented with single-tuyere injection of natural gas. Since then particularly in the last three or four years, the number of blast furnaces using some type of hydrocarbon addition has risen rapidly and now some 30 units are so equipped. Introduction of hydrocarbon additives permits a further increase in blast furnace temperature since the reducing agent which had been lacking becomes available. Further, less coke is required, the amount of coke reduction being limited by either the total amount of reducing agents present or by stove limits on hot blast temperature. In some cases blast temperatures approach 2,000°F; higher have been suggested, but the more common is below 2,000°F.

Petrochemicals

Air Oxidation of Aromatic Acids. W. W. Kaeding, R. O. Lindblom, and R. G. Temple. *Ind. Eng. Chem. 53,* 805 (1961) Oct. (4 pp.)

The catalytic oxidation of toluene to benzoic acid with air in the liquid phase is well known. When both air and steam are bubbled into liquid benzoic acid at a temperature of 200 to 240°C in the presence of dissolved copper benzoate, phenol, and CO_2 were the principal products of reaction. The conversion of toluene to phenol can than be visualized as a two-step air oxidation process consisting of an initial conversion to benzoic acid, followed by the transformation of the latter to phenol and CO_2. A heavy metal catalyst system has been perfected which makes it possible to oxidize liquid toluene to benzoic acid with high rates and yields exceeding 90%. In a similar manner, liquid benzoic acid was converted to phenol with air utilizing a copper catalyst and a metal promotor with yields approaching 90% in the laboratory. The only process chemical required is air, and the phenol is not contaminated with side reaction products.

Chemistry of Allene (Propadiene). IV. Carbonylation Reactions of Allene. T. J. Kealy and R. E. Benson. *Organic Chemistry J. 26,* 3126 (1961) Sept. (5 pp.)

The carbonylation of allene (propadiene) in water in the presence of ruthenium catalysts has given methacrylic acid. Derivatives of methacrylic acid were obtained when the reaction was conducted in the presence of methanol or amines. Under certain conditions a lactone, 3-hydroxy-1,3,4-trimethylcyclohexanecarboxylic acid lactone or an ester, dimethyl α, α-dimethyl-α-methyleneglutarate, were the major products of the carbonylation reaction in water and methanol, respectively.

Formation of Polycyclic Aromatic Hydrocarbons by Pyrolysis of Simple Aliphatic Hydrocarbons. I. E. Burrows and A. J. Lindsey. *Chem. & Ind.* 1395 (1961) Sept. 2.

Naphthalene, acenaphthalene, phenanthrene, pyrene, fluoranthene, 1,2-benzpyrene, 3,4-benzpyrene, anthanthrene, and coronene are all formed during pyrolysis of methane and ethylene. For each fuel gas a rise in temperature gives increased amounts of aromatic hydrocarbons, but at still higher temperatures smaller amounts are obtained. Similar results were obtained for butadiene and acetylene, and carbon was deposited in all the experiments.

Gases. S. C. Lind. *Nucleonics 19,* 43 (1961) Oct. (2 pp.)

In one or multicomponent irradiated gas systems a wide variety of different reactions occur that help radiation chemists find out more about chemical effects in gaseous matter. In gases atoms and molecules enter into different reactions when exposed to radiation than they do in solids or liquids. These reactions—induced primarily by ionizing or exciting agents from accelerators,

reactors, or radon—affect either one-component systems as in the case of ozone formation in oxygen, or more usually multicomponent ones. In the latter systems, for example, oxidation, hydrogenation, and polymerization as well as charge-transfer and energy-transfer reactions in foreign gases play an important role. In addition, reverse reactions occur when one-component systems dissociate under radiation to become multicomponent ones.

Intermediates in Solids. M. S. Matheson. *Nucleonics 19,* 57 (1961) Oct. (4 pp.)

Intermediate species found in irradiated solid aliphatic hydrocarbons, alcohols, polyethylene, ice, and nitrates support radiation chemistry mechanisms. But yields can be measured with only about 50% accuracy now. The electron spin resonances observed in normal aliphatic hydrocarbons after gamma irradiation can be attributed to radicals formed by the loss of a single hydrogen atom. It is surprising that in spite of the high energies available from secondary electrons, secondary hydrogens are lost in preference to the primary ones. Where comparisons can be made, the radicals observed are those postulated as important in radiolysis of those compounds as gases or liquids at higher temperatures. Little C-C bond breaking in straight chain hydrocarbons occurs, although the complex spectra of the branched hydrocarbons (neopentane and isobutane) suggest C-C rupture in these compounds; this difference agrees with usual radiation chemistry studies. For ethylene, presumably a hydrogen atom adds to ethylene to give an ethyl radical; the fate of the other fragment is unknown.

Isoprene from C_4 Cuts. A. Y. Giraud. *Chem. Eng. Processing 57,* 66 (1961) Sept. (7 pp.)

The isoprene process developed by the French I.F.P. is a two stage one. The first stage involves the use of the Prins reaction in which isobutlyene is reacted with formaldehyde under specific conditions to give 4,4-dimethylmetadioxane as the principal product. The 4,4-dimethylmetadioxane is then decomposed in the second stage, with recycle of the by-product formaldehyde.

Naphthalene from Petroleum. P. W. Sherwood. *Brennstoff-Chemie 42,* 283 (1961) Sept. (4 pp. German text)

Three American plants announced in 1960—Ashland, Sun Oil, and Tidewater—Collier-Carbon will be on stream at the end of 1961 producing 125,000 tons of naphthalene from petroleum. The 1960 demand was 263,000 and for 1965 will be about 340,000 tons. Approximately 80% of this amount enters phthalic anhydride production. Processes for dealkylation of methyl naphthalene and for hydrodealkylation of toluene are discussed.

A New Urea Synthesis. I. The Reaction of Ammonia, Carbon Monoxide, and Sulfur. R. A. Franz and F. Applegath. *Organic Chemistry J. 26,* 3304 (1961) Sept. (2 pp.)

Urea was prepared by a novel method based on two moles of ammonia to one each of carbon monoxide and sulfur. One mole of urea and one of hydrogen sulfide was produced. A mechanism, supported by experimental evidence, has been hypothesized for this reaction.

A New Synthesis of Ureas. II. The Reaction of Primary Aliphatic Amines with Carbon Monoxide and Sulfur. R. A. Franz, F. Applegath, F. V. Morriss, and F. Baiocchi. *Organic Chemistry J. 26,* 3306 (1961) Sept. (3 pp.)

Sulfur, carbon monoxide, and ammonia react at temperatures of about 100°. The present paper shows that this reaction is widely applicable to aliphatic amines, and high yields of 1,3-disubstituted ureas are obtained.

A New Synthesis of Ureas. III. The Reaction of Aromatic Amines with Carbon Monoxide and Sulfur. R. A. Franz, F. Applegath, F. V. Morriss, F. Baiocchi and C. Bolze. *Organic Chemistry J. 26,* 3309 (1961) Sept. (4 pp.)

Aromatic amines react only slightly under conditions which produce high yields of dialkylureas. However, in the absence of a solvent and with a tertiary amine catalyst, high yields of several diarylureas have been achieved. A study of the reaction conditions and the preparation of a variety of diaryl ureas are reported preparation of a variety of diarylureas are reported in this paper.

Oxidation-Liquid Phase. W. G. Toland and S. J. Lapporte. *Ind. Eng. Chem. 53,* 841 (1961) Oct. (5 pp.)

Growth potential of petrochemicals is paced by oxidation of hydrocarbons. Direct liquid phase oxidation of ethylene shows promise as a route to acetaldehyde. o-Phthalic and terephthalic acids are made from inexpensive toluene by chloromethylation and HNO_3 oxidation. Research activity shows heightened interest in air oxidation of paraffins and organometallics and the mechanism of chemical oxidations of hydrocarbons. This review covers the period April 1960 through March 1961; 59 references are covered in the bibliography.

Purification of Carbon Dioxide for Urea Synthesis. V. B. Diebold (assigned to Vulcan-Cincinnati, Inc.) U. S. 2,999,008 (1961) Sept. 5.

A process is claimed for purifying gaseous carbon dioxide for urea manufacture by reaction of ammonia and carbon dioxide. Contaminants of carbon dioxide are usually hydrogen, carbon monoxide, and methane. A stoichiometric amount of oxygen is admixed with the raw CO_2 and the mixture is passed through platinum, rhodium, or palladium catalysts at 100 to 300 psig at temperatures of 225° to 700°F. Water formed is removed by condensers.

Thermo Data for Petrochemicals. H. A. G. Chermin. *Petrol. Refiner 40,* 261 (1961) Sept. (3 pp.)

The heats of formation of dimethylsulfide, methylethyl sulfide, and methyl-n-propylsulfide are given in the literature. These data were calculated from measured heats of combustion. The heats of formation, after a slight correction for a recent redetermination of the heat effect of the reaction are given.

New Technology Boosts Markets for Petrochemical Tuolene. P. W. Sherwood. *World Petrol. 32,* 57 (1961) Oct. (5 pp.)

New toluene-consuming chemical technology began to

make itself felt in late 1960. Biggest single factor is the introduction of hydrodealkylation of toluene to benzene. This process was first commercialized in late 1960 (by South Hampton Co.) and is expected to provide a plant capacity of 97 million gal/yr by early 1962. Among the more important: a new route to phenol, a novel commercial synthesis for caprolactam, new toluene-based methods of terephthalic acid, and rapid growth in demand for tolylene isocyanate.

Polymerization

Polymerization. A. Chapiro. *Nucleonics 19,* 65 (1961) Oct. (4 pp.)

The field of radiation chemistry with commercial applications now is polymer chemistry. Advances with radiation-initiated polymers indicate that they form by free-radical and ionic mechanisms. Ionizing radiations have played an ever-expanding role in high-polymer chemistry in the last decade. The steadily growing interest of both polymer and radiation chemists in this field has been spurred on by the discovery of ways for making new plastic materials that have improved properties as well as manufacturing costs competitive with conventional methods. By 1955 it was found that radiations are particularly suitable for preparing graft copolymers. Since graft copolymers are equivalent in the field of high polymers to alloys in metallurgy, this development opens an immense range of new potential uses for polymer materials. The latest developments include polymerization of monomers at very low temperatures and crosslinking of polymers that normally degrade under irradiation. In the latter method, crosslinking is accomplished by adding solvents.

8. GAS DISTRIBUTION

Maintenance

Apparatus for Leak Testing. R. E. Fearon (assigned to Electro Chemical Laboratories Corp.) U. S. 2,999,162 (1961) Sept. 5.

An apparatus for detecting leakages in a closed vessel is claimed. A closed space or jacket surrounds the test vessel, which is filled with nitrogen under pressure, and an appreciable quantity of tritium gas. The jacket space is connected to a pump and a radiation detector that definitely shows the presence of any leaking tritium.

Pipe Line Leak Clamp. J. J. Watson, U. S. 2,999,515 (1961) Sept. 12.

A pipe line leak clamp is claimed for handling repairs on lines under pressure. The unit comprises a split sleeve, of a length to provide an annular sealing member at each end at a distance from the weakened leaking wall. This sleeve also carries a vented leak chamber which can be sealed about the leak area by rings after the sleeve is anchored in place.

Pipeline Cleaning Device. J. C. Buie and R. M. Rault. U. S. 3,000,028 (1961) Sept. 19.

An apparatus is claimed for inserting pig-balls into a pipeline for cleaning the latter. This comprises a transverse casing with end covers, with a coupling to pipeline, and to a sloped ball storage chamber. The ball chamber feeds a ball singly to a cage which is lowered by a sliding rod to a position aligned with the pipeline openings.

Report of the Committee for the Study of New Gas Distribution Techniques. *International Gas Union. IGU/3—61,* 8th International Gas Conference. Stockholm 1961. (24 pp.)

The first report was confined to a study of four aspects: the use of new materials and new methods of using traditional materials; legal requirements and recommendations contained in standards or codes of practice; the effect on the basic cost of distribution by alteration of pressure or velocity of the gas; and matters connected with service pipes, risers, and meters. The present report gives details of developments since 1958 on these subjects. Increasing use is being made of copper and plastic materials, particularly for gas service pipes, while asbestos cement, which was used for gas mains in several countries during a period of acute shortage of cast iron, is being used to a less extent except in Belgium where it appears to have a price advantage not experienced in other countries.

9. GAS FUEL UTILIZATION AND APPLIANCES

Burners

Gas Burner. J. R. Williams (assigned to Selas Corporation) U. S. 2,992,677 (1961) July 18.

An improved industrial burner formed of refractory material provides a combustion chamber having an elongated, restricted discharge slot. Metallic casing surrounds a portion of the slot to form a water jacket and openings in casing are provided to register with the slot. An adjustable sliding tube (water cooled) is provided to restrict the length of the slot, to regulate blast for heating selected portions of different sized work pieces.

Gas Range Structure. T. T. Arden and V. Weber (assigned to Robertshaw-Fulton Controls Co.) U. S. 2,993,532 (1961) July 25.

An improved gas range structure is claimed comprised of a combined burner box bottom and a gas manifold. The box bottom is formed by joining face-to-face, two lightweight rectangular metal sheets, with peripheral pressed-in channels to form a looped gas manifold. Burner and pilot channels are also preformed by pressure. A row of burner controls is provided along the top front of the manifold, and filters are claimed for pilots.

Industrial Gas Burner. J. B. Henwood (assigned to Selas Corporation) U. S. 2,992,676 (1961) July 18.

An improved burner for a furnace wall is claimed in which combustion products are used to preheat the entering combustion air. The assembly comprises a refractory burner block with a cup-shaped depression

for the flame, and an opening from the base of the depression through the block which carries triple concentric passages. The outer passage is for gas, the middle for air, and the inner or axial passage is for withdrawal of hot products of combustion, which travel outward to preheat the adjacent ingoing air annulus.

Dryers, Clothes

Lint Remover for Clothes Drier. C. A. Cobb and H. H. Morris (assigned to Whirlpool Corporation) U. S. 2,996,810 (1961) Aug. 22.

A lint removing device for domestic clothes driers is connected to the drier across the outlet air stream. Within a housing a porous membrane, moved as a filter belt by lower rollers, is drawn downward across the air conduit. This membrane of combustible material when loaded with lint, produces a back pressure in the air conduit which energizes a motor to advance the membrane exposing a fresh porous surface. The coated portion dropped to a lower chamber, is ignited by an intermittently actuated heater and consumed.

Combustion

The N.I.F.E.S.* Chart: A New Method of Estimating the Loss of Sensible Heat in Flue Gases. T. F. Hurley and G. R. Stern. *J. Inst. Fuel 34,* 393 (1961) Sept. (13 pp.)

The authors have attempted to devise a simple but reasonably accurate method of estimating the sensible heat lost in flue gases from information which is available after carrying out even the simplest boiler trial. For this purpose they have used the percentage of CO_2 ($+SO_2$) in the flue gases and their exit temperature to ($+ SO_2$) in the flue gases and their exit temperature to indicate combustion conditions. The calorific value of the fuel is used as a measure of its type and properties. Working from first principles and generally accepted experimental results, a series of formulae is derived which can be used either algebraically with the aid of tables or in the form of two charts. One of these charts enables the sensible heat loss to be obtained quickly and easily as Btu/lb of fuel, and the other is a percentage of the heat in one pound of fuel. Both solid and liquid fuels are covered. To check the accuracy of the method, heat losses were worked out for a range of actual fuels.

*National Industrial Fuel Efficiency Service.

Cookers

Cooking Oven. L. E. Wolske (assigned to Whirlpool Corp.) U. S. 2,997,041 (1961) Aug. 22.

A cooking oven is claimed with improvement in the combination of the upper and lower doors. These are hinged at upper and lower edges of the oven opening for a vertical swinging movement in open, closed, or intermediate positons. Pairs of door-controlling links extend to the rear along guide tracks on oven sidewalls, with roller ends engaged to meet the depressions in the guide track to determine the open positions of the doors.

Flame Cultivation

Field Drying of Grain Sorghum. D. Price and T. C. Longnecker. *LP-Gas 21,* 37 (1961) Oct.

The field drying of grain sorghum, one of the newer applications of LP-Gas flaming will continue on an experimental basis at the High Plains Research Foundation this fall. A flame cultivator using metal hoods was designed to retain heat in the drying area.

Flame Cultivation of Row Crops. D. Price and T. C. Longnecker. *LP-Gas 21,* 30 (1961) Oct. (5 pp.)

The use of flame cultivation to control weeds in cotton, grain sorghum, and soy beans during 1959 indicated its possibilities as a weed control measure and, because of this, a more detailed study of flame cultivation to control weeds in cotton and other row crops was initiated in 1960. These row crops included not only cotton, but also grain sorghum, corn, castor beans, and soybeans. The flame cultivation research program on cotton in 1960 included tests with different tractor speeds, and pressure settings, cross and parallel flaming, pre-emergence flaming, size of cotton at first flaming, and the use of smaller or "midget" burners.

High Plains Research Sells Flame Cultivation. W. M. Bone. *LP-Gas 21,* 22 (1961) Oct. (5 pp.)

Many row crops will withstand more heat, properly applied, than most of the grasses, weeds, and vines with which they compete for plant food, moisture, and space in the cultivated row. With specially designed equipment, an LP-Gas flame is directed either parallel to or across the cultivated row at the base of the plant so it will destroy young weeds without injuring older and hardier crops. It must be remembered that flame cultivation does not eliminate the need for hand hoeing. Hoe bills, however, have been reduced by one-third to one-half—a saving of from $5 to $10 per acre.

LP-Gas Weed Flaming in Colorado. J. A. Thompson. *LP-Gas 21,* 28 (1961) Oct. (2 pp.)

Irrigated farming presents problems of its own, with regard to weeds. The control of weeds in irrigation ditches is a matter of prime importance to all water users. Under some conditions, as much as 25% of the water running through the ditches may be absorbed by weeds growing in or along the banks. Such a loss is serious and often a dangerous one for the farmer. Weed clogged ditches are likely to silt up and water flow is badly retarded.

On-The-Farm Report: Flame Cultivation. A. B. Kennerly. *LP-Gas 21,* 26 (1961) Oct. (2 pp.)

Experiments in Texas, Louisiana, Arkansas, and Mississippi have shown that flame cultivation is satisfactory when it is a part of a series of treatments. The following steps were found to be good practice: pre-emergence chemical treating at planting time; post-emergence oil treatment one to three times as needed on the drill area, and sweep cultivation of middles; and flame cultivation.

Flame Research

Burning Velocities of Hydrocarbon Flames. S. A. Weil. (Chicago: Institute of Gas Technology Research Bulletin No. 30. March 1961; $5.00)

Results are presented on the burning velocities of selected gaseous fuels in Bunsen-type flames. Flames of fuel-lean mixtures of these fuels with oxygen and diluent (inert) gases were studied for determination of the effects of fuel composition, the nature of the diluent gas, flame temperature, and oxygen/fuel ratio. Among the fuels used were methane, propane, ethylene, and hydrogen, and binary mixtures of them. The effect of the diluent gas was examined through the use of nitrogen, helium, and argon, in methane-oxygen-diluent mixtures. The oxygen/fuel ratios ranged from stoichiometric to nearly 600% excess oxygen; the flame temperature levels, from 1800 to 2500°K. Flames of fuel-rich mixtures of methane and air in secondary atmospheres of oxygen with varying amounts of nitrogen and carbon dioxide were investigated. The primary gas composition was varied from 20% to 100% aeration.

Burning Velocities of the Hydrogen Peroxide Decomposition Flame. C. N. Satterfield and E. Kehat. *Combustion and Flame 5*, 273 (1961) Sept. (10 pp.)

Burning velocities of the hydrogen peroxide decomposition flame have been measured by the bunsen burner method at pressures between 0.5 and 1 atmosphere. The flame reaction follows approximately first order kinetics with an activation energy of 35 kcal/mole, and shows general agreement with the mechanism and kinetics of the homogeneous non-flame reaction. A single plot of the logarithm of the product of the square of the burning velocity and the pressure *vs.* the reciprocal flame temperature correlated the data obtained here at all pressures and also burning velocities above liquid solutions of hydrogen peroxides.

Chronology and Topography of Sparks at Minimum Energy for Ignition. E. L. Litchfield. *Combustion and Flame 5*, 235 (1961) Sept. (7 pp.)

Microsecond exposure schlieren observations of ignition kernels and developing flames are reported for a set of minimum energy conditions holding for electrostatic spark ignition of 8.5% methane-air mixtures at 0.1 atmosphere initial pressure. Time of appearance of a flame and the extent of influence of the shock wave generated by the electric discharge were determined experimentally. A time of appearance investigation was also reported by Linten and Wooding; their mixtures were at one atmosphere initial pressure.

Effect of Temperature on the Ignition Characteristics of Hydrocarbons. K. C. Salooja. *Combustion and Flame 5*, 243 (1961) Sept. (5 pp.)

The ignition lag/temperature relationship and the effect of fuel-air composition on this relationship have been investigated for *n*-heptane, methylcyclohexane, isooctane, diisobutylene, benzene and ethylbenzene, from temperatures near their minimum ignition points to 800°C. Marked changes in the ignition characteristics have been shown to occur with increasing temperature. In general, as the temperature is increased: ignition lag decreases; the slope of the ignition lag/temperature relationship becomes less steep; and the marked effect of fuel-air composition observed near the minimum ignition point decreases and eventually tends to disappear.

Pressure Dependence of Laminar Burning Velocity by the Spherical Bomb Method. J. T. Agnew and L. B. Graiff. *Combustion and Flame 5*, 209 (1961) Sept. (11 pp.)

The effect of pressure on the burning velocity of 4 fuel-air and 3 fuel-oxygen mixtures, all in stoichiometric proportions, was determined using the constant-volume bomb method. Ionization gaps were employed to obtain the flame radius/time data. The pressure range investigated was from 0.2 to 20 atmospheres. Burning velocity values were calculated from flame speed measurements using the recently developed equations of Eschenbach and Agnew. Possible sources of errors which are peculiar to the ionization gap technique of measuring flame speeds are discussed along with the precautions taken to minimize their effects.

Rate of Combustion from Free Surfaces of Liquid Hydrocarbons. W. L. Fons. *Combustion and Flame 5*, 283 (1961) Sept. (5 pp.)

The burning velocity of *n*-hexane and cyclohexane as related to the area of the burning fuel surface was studied with 10 open pans ranging from 0.22 to 11.94 in. in diameter. On the 4 larger pans, fuel temperatures were also measured during the burning period at 2 depths below the surface. For small pans less than 5 in. in diameter, burning velocity decreased with increasing pan size. For pans greater than 5 in. in diameter, burning velocity increased with increasing pan size. Thus, there appear to be 2 burning regimes in the range of pan diameters tested, a laminar flow regime on the larger pans. This observation is in agreement with the experimental results reported by others for equivalent pan sizes burning less volatile hydrocarbon fuels.

Technique for Sampling Reaction Intermediates in a Rapid Compression Machine. L. H. S. Roblee, Jr. *Combustion and Flame 5*, 229 (1961) Sept. (6 pp.)

A technique devised for rapidly quenching reactions occurring in a rapid compression machine during the ignition delay period is described and the results of preliminary studies made with it are presented. The quenching device was designed and adapted to the machine to extend its utility and provide a means of studying the chemical reactions preceding the autoignition. With this device preflame reactions can be arrested at any predetermined point during compression or ignition delay. Suitable techniques may then be employed to analyze the partial oxidation products. An initial invstigation with the device was conducted on the stoichiometric benzene-air system.

Thermochemical Equilibrium in Hydrocarbon-Oxygen Reactions Involving Polyatomic Forms of Carbon. N. R. Gay, J. T. Agnew, O. W. Witzell, and C. E. Karabell. *Combustion and Flame 5*, 257 (1961) Sept. (16 pp.)

Equilibrium composition and flame temperatures have been calculated for the reaction of acetylene and ethylene with oxygen over a range of mixture ratios. Emphasis has been placed on the determination of con-

ditions necessary for the formation of solid carbon in the products. The influence of the presence of long chain carbon molecules on the mixture ratio and temperatures required for carbon deposition has been investigated. Premixed flames of acetylene and ethylene with oxygen have been studied experimentally to determine the correlation between theoretical calculations and actual combustion reactions.

Fuel Utilization

Corrosion Control Aspects of Central Station Heating and Cooling. W. W. Steinert. *Gas Age 128,* 27 (1961) Sept. 14 (4 pp.)

Cost of maintenance is a key to profitable operation of this type of system. The cost can be greatly increased by uncontrolled corrosion of major components. With today's high construction costs, possible corrosion problems must be carefully analyzed and measures taken to keep these problems to a minimum. The Hartford system has already worked out such problems.

Heat Transfer

Measurement of Mean Temperature in a Duct. R. V. DeLeo, F. D. Werner, and F. W. Hagen, *Instruments & Control Systems 34,* 1659 (1961) Sept. (3 pp.)

When fluid flows in a pipe or duct, there is a radial velocity gradient. If the wall temperature is not the same as the fluid temperature, there also will be a radial temperature gradient. The mean or average temperature is not the temperature at the center and the center is not the best place to locate a temperature sensor. Calculations are shown for the best location of a sensor in a long straight pipe.

Predicting Heat Transfer Coefficients for Film Flow. A. E. Dukler. *Petro/Chem. Eng. 33,* 46 (1961) Oct. (8 pp.)

Design charts based on a newly published theoretical analysis provide the engineer with valuable tools for calculating average coefficients for transfer of heat through thin films. The analysis also describes variables involved in determining heat transfer coefficients for such process equipment as condensers, falling film evaporators, gas-liquid reactors, thermosiphon reboilers, and steam generators. Presented along with the charts are related equations and a discussion of their use.

Hydrogen Production

Water Gas Conversion in Today's Technology. P. W. Sherwood. *Petrol. 24,* 338 (1961) Sept. (3 pp.)

Of the various methods for hydrogen production, steam reforming, and partial oxidation of hydrocarbons (especially methane) are the most important. In 1959, these 2 processes constituted the hydrogen source for 72% of the United States installed capacity for the production of ammonia, the largest single chemical consumer of hydrogen. This route eclipses the principal competitive hydrogen sources: reforming tail gas (10.6% of ammonia capacity) and electrolysis (7.4%).

Industrial Heating

Automatic Brazing Opens Bottleneck in Heating Element Production. T. L. Sherman, *Ind. Gas 40,* 3 (1961) Sept. (2 pp.)

The John J. Nesbitt plant in Philadelphia was able to expand production schedules by the use of automatic brazing techniques. In addition to a five-fold increase from an average of 40 to 200 brazed units per day, rejects were cut from 23% to only 2% and production efficiency and uniformity of quality were improved.

Gas Burner Structures. G. Zimmerman (assigned to Owens-Illinois Glass Co.) U. S. 2,995,184 Aug. 8, 1961.

An improved elongated glass-working burner is claimed in which flash-back of high oxygen-natural gas mixtures is eliminated. The assembly comprises a mixer-chamber, with high velocity outlet leading to an expansion chamber in the lower burner body. This chamber feeds a second double row of high velocity orifices which feed a row of expansion chambers, (one for each orifice) and the latter discharge through high velocity orifices to the burner ports. Any back-flash tendency is blocked by high velocity in the last (top-plate) expansion chamber.

Growth of Industrial Gas on Factory Estates. H. Capper. *Gas J. 307,* 279 (1961) Sept. 6 (7 pp.)

The South Eastern Industrial load in 1960 was 39,655,400 therms with 7,625 industrial consumers, and has shown the smallest increase of all the gas boards during the year. This trend is also seen in the results of the North Thames Gas Board. The table shown gives a guide to where the markets lie and also indicates their potential load. In order to arrive at definite conclusions, the information needs to be supported by a thorough survey of the type of trade uses, locality, and the effect of local industries, and general trade conditions.

How Natural Gas Serves Industry in "The Heart of TVA." A. Q. Smith. *Ind. Gas 40,* 3 (1961) Sept. (2 pp.)

Here is a survey of eight typical plants with diversified products that use varying quantities of natural gas despite location in Chattanooga, Tennessee, "electrical center." These are textile machinery, tufted carpeting manufacture, plumbing fixtures, bottle manufacture, chemical production, ceramics firing, water heating, and grain dryers.

Open Coil Annealing. V. J. Gibbons. *Gas World 154,* 40 (1961) Sept. 16 (3 pp.)

A newly developed annealing method for sheet and tinplate called "open coil annealing" combines the best features of conventional box and continuous annealing without their inherent disadvantages. "Open coil annealing" provides "air space" or "separations" between the individual wraps of a coil allowing circulation of the hot annealing atmosphere. The entire coil can thus be heated and cooled much more rapidly and uniformly than in conventional box annealing. De-

sirable-gas-metal reactions can be carried to completion when the coil is "open" during annealing. Facilities are available for mixing many types of annealing atmospheres, and for adding controlled quantities of water vapor. To measure temperatures during the entire annealing cycle, thermocouples can be located at 6 positions in a number of open coils.

Ore Reduction

Energy Requirements for Iron Ore Reduction. R. Wild. *J. Inst. Fuel. 34,* 381 (1961) Sept. 12 pp.

The possible ways of reducing iron ore to metal are outlined: metallic reductants, carbon, gaseous reductants. The basic ore reduction reactions are considered and methods of supplying the energy deficit which occurs when carbonaceous reductants are used are discussed. The heat generated when carbon and methane are burnt is considered in detail and the concept of theoretical efficiency is outlined. The various processes which have been suggested are classified according to the fuel used and briefly described. They are compared on an energy basis and two standards of comparison are put forward. One, the smelting efficiency is based on the total energy supplied compared with that necessary for reduction and heating while the other, the thermal efficiency, also takes note of the energy content of the gases leaving the system. Finally iron-making processes are compared, from an energy standpoint, in a single diagram.

Ore Reduction. T. H. Whaley (assigned to Texaco Development Corp.) U. S. 2,997,383 (1961) Aug. 22.

A process for reducing iron ore consists first of passing a hot gas mixture of hydrogen and carbon monoxide upward through the ore bed at 1750°F and 200 psig until about 85% reduction is obtained. A part of the reduced product is treated separately with steam at 385 psig and 935°F which reoxidizes some ore but generates hydrogen. The hydrogen is used to complete the reduction of the next batch of 85% reduced ore. The reoxidized ore product is again reduced by the H_2 and CO mixture and returned to the final reducer. Two, three, and four stage batch treatments may be used.

Ventilation

An Evaluation of the Various Methods for Attaining Cooler Domestic Gas Kitchens. L. A. Nead and B. G. Honaker. (A.G.A. Laboratories Res. Bull. 89, Project DA-6-C: Sept. 1961; 40 pp. $2.50)

Various methods for minimizing appliance operation heat losses to domestic gas kitchens were examined and evaluated in a literature search. Emphasis is placed first on minimizing these heat losses to the kitchen by means of improved equipment performance and/or design and second by means of improved venting or ventilation methods. In some instances, limited experimental studies supplement the literature findings (40 references).

10. EQUIPMENT AND INSTRUMENTATION

Heat Transfer

Explicit Solutions of the One-Dimensional Heat Equation for a Composite Wall. M. Ascher. *Math. Comput. 14,* 72, 346 (1960) Oct. (8 pp.) [From *Appl. Mech. Rev. 14,* 727 (1961) Sept.]

An explicit finite difference scheme to solve the title problem is considered. The possible choices for the time mesh Δt are discussed. The need for such a study arises since a uniform choice of Δt throughout the whole structure is not economical. For each case convergence is proved. An example illustrates the theory. A comparison of computing time is provided.

Y. L. Luke

A Problem in the Theory of Heat Conductivity. R. I. Gavrilova and A. P. Prudnikov. *Inzhener.-Fiz. Zh. 136* (1960) May (2 pp. Russian text) [From *Appl. Mech. Rev. 14,* 727 (1961)]

The heat-conduction equation with a heat source is solved for a cylindrical annulus. The solution is found as a Dini-Bessel expansion.

From authors' summary

Calculating Heat Exchanger Shell Side Pressure Drop. D. L. Whitley. *Chem. Eng. Progress 57,* 59 (1961) Sept. (7 pp.)

For a sound engineering design of a shell and tube heat exchanger, an accurate correlation to calculate the shell side pressure drop is required. Four published well-known correlations were evaluated with field data taken from nine heat exchangers in plant operation. The four correlations are: Williams, Katz, and Donohue; Kern; Buthod; and Bell. Some surprising discrepancies were found. Bell's correlation was determined to be the most accurate. A detailed explanation and example of Bell's correlation was given.

New Charts for Hydrocarbon Vapor-Liquid Equilibria. S. T. Hadden and H. G. Grayson. *Petrol. Refiner 40,* 207 (1961) Sept. (12 pp.)

Extensions, improvements, and a consolidation of the vapor-liquid equilibria correlations of Hadden and Winn are presented, which use convergence pressure as a composition parameter. These extended correlations, which are in nomographic form, apply to light hydrocarbons and petroleum fractions at temperatures from −260° to 800°F and at pressures up to 10,000 psia, and to certain non-hydrocarbon systems.

11. MATERIALS OF CONSTRUCTION, AND CORROSION

Cathodic Protection

Cathodic Protection for Underground Gaslines. P. W. Sherwood. *Gas J. 307,* 356 (1961) Sept. 20 (3 pp.)

In gaslines, corrosion may be caused by exposure to air and other gases; water and corrosive chemical fluids; and the soil—where actually is found a combination of salt-bearing water and oxygen at work. Cathodic protection may theoretically be applied for any of these situations. However, protection against corrosion by conditions in the first and second categories may usually be provided by less costly means—though the approach to the categories differs radically. Corrosion in the soil is the big, although not the only, field of cathodic protection.

Galvanic Anodes and Fresh Water Rinse Reduce Tanker Corrosion. E. E. Nelson. *Corrosion 17,* 463t (1961) Oct. (6 pp.)

Based on inspection of more than a thousand tanker cargo compartments, types of corrosion are classified under 4 operating conditions. These are the presence or absence of ballast water and petroleum material cargoes of low or high viscosity. Pitting in crude tankers is explained as simple galvanic corrosion. Data and experience with successful cathodic protection systems using magnesium and zinc anodes are discussed. At present the zinc systems appear to be more economical. Data are presented showing that appreciable hydrogen is generated by magnesium systems but not by zinc systems. The benefits of fresh water rinsing are indicated by test panel data and from inspections.

Coatings

Automatic Time-Temperature Programming of Tube-Coating and Baking Operations. *Ind. Heating 28,* 1733 (1961) Sept. (5 pp.)

Plastic Applicators, Inc. is the world's largest applicator of various types of plastic coatings for corrosion control of oil field tubings. This is the process used to apply the coatings to the interiors of tubing approximately 30 ft in length and of sizes varying up to 2⅞ in. internal diameter.

Polyester and Epoxy Based Non-Solvent Coatings for Corrosion Control. W. C. Hodges and J. J. Bogner. *Corrosion 17,* 34 (1961) Oct. (6 pp.)

Non-solvent coatings based on polyester and epoxy resins give thicker films in one application than do conventional solvent type coatings. The article briefly describes special spraying equipment required for these non-solvent systems. Suggested application procedure is given. Comparisons are also made on shrinkage rates of non-solvent and solvent type epoxies. Cost comparisons are made also between the 2 systems, showing the cost advantages derived from the thick one-coat applications obtainable with the non-solvent coatings.

Construction Materials

Design Techniques for Sizing Packed Towers. J. S. Eckert. *Chem. Eng. Progress 57,* 54 (1961) Sept. (5 pp.)

The general design correlation is discussed, along with the effect of the more important variables connected with packed tower design. Design procedure is given for sizing packed towers, with rules determining type and size of packing. The influence of surface tension and foam are discussed. Proper distribution, redistribution, hold down, support, determination of size, and type of packing are also discussed. Charts are supplied which give design data required for sizing packed towers.

Corrosion

Stray Current Corrosion, Its Origin and Control. G. Heim. *Gas u. Wasserfach 102,* 901 (1961) Aug. 18 (9 pp. German text.)

In contrast to corrosion in electrolytic cells, in stray current corrosion active current is produced from outside sources. In neutral electrolytes, where most soils may be classified, the strength of the corrosion current in both types of corrosion is determined by the diffusion of the oxygen. Through measurement of the metal electrolyte potentials, the position of the anode and cathode regions, and whether an actual corrosion element is present, or if stray current corrosion is occurring can be determined. Due to large-surface corrosion elements involved, it is possible to draw conclusions from the temporary course of the metal electrode potentials (MEP) and the pipe measurements. Protective measures presently used, depending upon conditions, are the introduction of insulating flanges, connection of metal blanks in the zone of current exit, use of dense coatings, and stray drainage methods.

Metals

Corrosion Resistance of Titanium, Zirconium, and Tantalum Used for Chemical Equipment. C. A. Hampel. *Corrosion 17,* 9 (1961) Oct. (6 pp.)

Attractive properties of titanium, zirconium, and tantalum for fabrication of equipment used in corrosive environments of the chemical industry are detailed. Relation of hydrogen absorption and resistance to numerous corrosives at varying temperatures are related in the text and tabulated data. Some special problems faced when these metals are fabricated are considered and solutions of some are described. Some typical examples of equipment fabricated of titanium, zirconium, and tantalum are shown.

Titanium. Data compiled by Union Carbide Metals Co., Div. of Union Carbide Corp. *Design News 16,* 65 (1961) Sept. 29 (24 pp.)

Tables represent all major commercial titanium producers and melters. More information is presented than has previously been available in any one publication. The 51 commercial and alloyed titaniums listed in the tables are generally available in commercial quantities on order. Tables are grouped by producer and are arranged in sequence: Unalloyed, Alpha Alloys, Beta Alloys, and Alpha-Beta Alloys.

Plastics

Thermoplastic Pipe Fittings and Equipment for Corrosion Control. R. W. Johnson and A. E. Webb. *Corrosion 17,* 30 (1961) Oct. (3 pp.)

Principal characteristics of thermoplastics currently used

for corrosion resistance are described. Some of the advantages of plastic piping over metallic piping are shown. Types of plastic materials described briefly include polyethylene, Acrylo-Butadiene-Styrene (ABS), cellulose acetate butyrate, vinylidene chloride, PVC (polyvinyl chloride), and chlorinated polyether. It also describes plastic lined steel pipe, joints, fittings, and valves. Additional data given on PVC, include case histories on service of PVC with illustrations of several installations.

Spray Both Plastic and Reinforcement. *Chem. Eng. 68,* 222 (1961) Oct. 16 (2 pp.)

Novel spray gun chops up glass fibers and combines them with sprayed-on plastics, in a single operation. The main advantages of the new technique are speed and ease of application.

12. ANALYTICAL METHODS AND TESTS

Analytical Instruments

Costly Giants of the Modern Laboratory. *Business Week* 62 (1961) Oct. 7 (3 pp.)

Many of the new laboratory tools are turning out to have unexpected new uses. The electron microscope is developing spectacular new uses all the way from medical research to studies of adhesion. The impact of the much later field emission microscope, which makes it possible for scientists actually to break down the atom and examine its parts, hasn't even begun to be felt, yet. Emission spectroscopes, mass spectroscopes, activation analysis instruments, and vapor phase chromatography equipment—essential in every research field from plastics to food—is available in a wide variety and quantity.

A Direct Reading Constant Volume Gas Thermometer. J. K. Hulm and R. D. Blaugher. *Cryogenics 1,* 229 (1961) June (2 pp.)

A constant volume helium gas thermometer was made direct reading by utilizing a low dead space aneroid manometer for pressure determination. This arrangement eliminates the time consuming adjustments which are characteristic of the constant volume gas thermometer when a mercury-in-glass manometer is used. The new system is easy to calibrate, rapid reading, and permits temperatures between 4.2 and 20°K to be determined with an accuracy of 0.02°K.

The Thermosiphon as a Nitrogen Cryostat for Operation in the Horizontal Reactor Channel. L. Bewilogua and R. Knoner. *Cryogenics 2,* 46 (1961) Sept. (2 pp.)

A 2-phase closed circuit according to the thermosiphon principle allows cooling of samples which are arranged at a large distance or are located at points of difficult access, even in cases of considerable heat supply. With the model described, a temperature of 80°K was attained at a distance of 2 m using nitrogen. This temperature could be maintained for a long period even under unfavorable conditions, such as heat supply of up to 500W, poor insulation, and partial evaporation of the external cooling liquid.

Carbon Monoxide

Infrared Spectrum of Solid Carbon Monoxide. G. E. Ewing and G. C. Pimentel. *J. Chem. Phys. 35,* 925 (1961) Sept. (11 pp.)

The infrared spectrum of solid carbon monoxide at 20°K has been examined in the fundamental and overtone regions. Sharp features (bandwidths about 1 cm^{-1}) are assigned to vibrational modes of the isotopic species: $C^{12}O^{16}$, 2138.1 cm^{-1}; $C^{12}O^{17}$, 2112.3 cm^{-1}; $C^{13}O^{16}$, 2092.2 cm^{-1}; and $C^{12}O^{18}$, 2088.4 cm^{-1}. These frequencies are examined with the aid of existing theories of frequency shifts in condensed phases. A broad adsorption (bandwidth about 40 cm^{-1}) centered at 2208 cm^{-1} is assigned to combinations of the fundamental mode with lattice modes. Calculations suggest that the lattice modes involved probably include translations as well as librations.

Chromatography

The Design and Construction of a Two-Inch Preparative Gas Chromatographic Column. G. J. Frisone. *J. Chromatography 6,* 97 (1961) Aug. (13 pp.)

Factors which control the design of a large column, such as column size, sample size, carrier gas flow, injection system, and condensing system are discussed. Other points of interest such as capillary by-pass and sample detection, packing problems, gas recycle, study of efficiency *versus* flow rate and efficiency *versus* sample size are also treated. A brief survey of material costs is given.

Mass Spectra

Comparison of the Mass Spectra of Extracts and Vacuum Pyrolysis Products from Coal. A. G. Sharkey, Jr., J. L. Shultz, and R. A. Friedel. *Fuel 40,* 423 (1961) Sept. (4 pp.)

Mass spectra of a vacuum pyrolysis condensate and a methanol-benzene extract of coal indicate that the materials contain similar major constituents. Quantitative analyses were carried out based on structural types found in coal carbonization products. Carbon number distribution data were obtained by mass spectrometry using low-ionizing-voltage techniques.

Measurement

Measurements of the Pressure Dependence of Liquid Normal Hydrogen. A. Van Itterbeek and O. Verbeke. *Cryogenics 2,* 21 (1961) Sept. (2 pp.)

Measurements of the dependence of the density of liquid normal hydrogen on pressure are carried out below 20°K and up to near the melting curve (150 kg cm^{-2}). Comparison is made between present measurements and existing ones on liquid hydrogen by Bartholome and Johnston. The former were carried out below 20°K and the latter above 20°K. Very good agreement is found for present results at the normal boiling point,

especially with those of Johnston. However at the lower temperatures, a large difference appears against the data of Bartholome. Comparing the velocity of sound calculated from present results or from those of Bartholome with present experimental values, a good agreement was found except for Bartholome's values at the lower temperatures. Another conclusion following from these measurements is that Eucken's equation for density as a function of pressure has to be reconsidered.

Thermomechanical Pressure Measurements in Liquid Helium—II. S. M. Bhagat and P. R. Critchlow. *Cryogenics 2,* 39 (1961) Sept. (4 pp.)

Measurements of the thermomechanical pressure have been carried out on capillaries of 0.01—0.08 cm diameter between 1.3 and 1.8°K. In all cases the behavior showed a marked change at a critical heat current. Below this value the only process of dissipation is the viscosity of this normal fluid. While above the critical heat current mutual friction can explain the observed temperature differences it is insufficient to account for the pressure differences. An attempt has been made to explain this discrepancy by the existence of an eddy viscosity in the superfluid.

Nickel

Analysis of Raney Nickel Catalyst. S. D. Paul and M. S. Krishnan. *J. sci. industr. Res. (India) 20D,* 333 (1961) Sept. (3 pp.)

A simple and efficient method is described for the volumetric estimation of aluminum and nickel in Raney nickel catalyst and its alloy. The method makes use of the great stability of aluminum triethanolamine and nickel cyanide complexes as compared to that of the corresponding complexes with ethylenediamine tetracetic acid. The method can also be used for the estimation of aluminum and nickel when present alone.

Oil Shales

Constitution of Hydrocarbon-like Materials Derived from Kerogen Oxidation Products. W. E. Robinson and D. L. Lawlor. *Fuel 40,* 375 (1961) Sept. (14 pp.)

The organic acids present in a Colorado oil shale oxidation product were characterized. This was accomplished by reducing the acids to hydrocarbons and fractionating the resulting material. Data from this study indicated that the oxidation product contained *n*-paraffinic, isoparaffinic, aromatic, naphthenic, and heterocyclic acids. The latter 2 types predominated, suggesting that Colorado oil shale kerogen contains mostly alicyclic and heterocyclic structures, with smaller amounts of straight chain and aromatic constituents.

Shock Tube

The Shock Tube as a Tool in Fuel and Combustion Research. H. B. Palmer. *J. Inst. Fuel 34,* 359 (1961) Sept. (9 pp.)

The first half of this paper tells what shock tubes are and how they operate. The second half deals with their use in fuel and combustion research. Shock tubes, as applied to the study of fuels and combustion, have a history covering less than ten years. During this brief period, shock tube research has contributed much to knowledge of the kinetics of fast gaseous reactions, including a good deal of work on hydrocarbons and various oxidizers. The prime virtue of the shock tube method is that it heats the reacting system at an unusually fast rate, at least 1,000 times faster than can be attained by more conventional techniques. It also permits coverage of an extremely wide temperature range, from ambient up to temperatures where ionization is very significant. Applications of shock-tube methods to the study of liquid and solid fuels have been meager, but are being explored.

Ultrasonics

An Apparatus for Studying Ultrasonic Absorption in Metals at Low Temperatures. A. A. Galkin and A. P. Korolyuk. *Cryogenics 2,* 48 (1961) Sept. (5 pp.)

An apparatus is described for measuring the ultrasonic absorption coefficient in metals at low temperatures. The absorption in the frequency range 50—250 Mc/s can be determined, recorded on a 2-dimensional plotter.

13. BASIC SCIENCE

Adsorption

General Theory of Monolayer Physical Adsorption on Solids. W. A. Steele and M. Ross. *J. Chem. Phys. 35,* 850 (1961) Sept. (13 pp.)

By suitable modifications of the general equations given previously, a theoretical monolayer adsorption isotherm is given which is written as a power series. The terms in the series involve integrals over the interaction energies of the adsorbed atoms with each other and with the solid. This treatment is based on a virial expansion of the density of the film in powers of the activity of the film, but differs from previous 2-dimensional virial expansions in that it explicitly includes the effect of periodic variation of the solid-gas atom potential energy as the atom moves over the surface of the solid. This general equation reduces to a sitewise model for large parallel variations in the solid-gas atom energy, and to a perfectly mobile film for small variations.

Cryogenics

Low Temperature Refrigeration. M. Ruhemann. *Cryogenics 1,* 193 (1961) June (6 pp.)

Normal commercial refrigeration, where heat is absorbed at temperatures not far below ambient, generally uses vapor compression cycles because the enthalpy reduction caused by the condensation of conventional type refrigerants is large compared with that obtainable by the isothermal compression of "permanent" gases, and because the required temperature difference between condensing and evaporating sides is small enough to permit the use of practically acceptable compression ratios. Refrigeration at hydrogen temperatures is today required in three distinct fields of application: distilla-

tion of hydrogen/deuterium mixtures for heavy water production; production of liquid hydrogen as a rocket fuel; and refrigeration of large bubble chambers for experiments in nuclear physics. Quite irrespective of the different sizes of installations to serve these various purposes, the type of cold requirement is very different in the three cases.

A New Refrigeration Cycle for the Production of Liquid Nitrogen. S. C. Collins and R. W. Hughes. *Cryogenics 2,* 43 (1961) Sept. (3 pp.)

A novel arrangement of reversing exchangers which are cooled by expanded nitrogen makes possible unattended operation of a liquid nitrogen plant for long periods of time. Air for use in the distillation column is compressed to 5 atm and purified by refrigeration. Unlike procedures in earlier cycles employing reversing exchangers the functions of refrigeration and rectification are separate. The refrigerant stream is pure nitrogen except for the starting period when air is used. The pressure range is from about 4.5 to 37 atm. Compression takes place in two stages, expansion in one stage. Several small liquid nitrogen plants based on this cycle have been in service for over a year.

Density

Saturated Liquid Densities for Binary Hydrocarbon Systems. E. M. Phillips and G. Thodos. *A.I.Ch.E. J. 7,* 413 (1961) Sept. (5 pp.)

The extension of the rules proposed by Cailletet and Mathias for the sum of the saturated vapor and liquid densities and by Guggenheim for the difference of these densities enabled the development of a method for the prediction of liquid densities for binary hydrocarbon systems at saturated conditions. The theorem by corresponding states indicated that unique relationships should exist between the reduced temperature and the sum and difference of the reduced saturated liquid density and the reduced saturated vapor density. The method developed in this work reproduces the saturated liquid densities of the 4 systems within 4.8%. In addition, saturated densities have been calculated for the ethylene-*n*-heptane system and checked the experimental values within 3.2%. At present this method can be applied only to hydrocarbon mixtures whose dew point does not exceed twice its atmospheric boiling point.

Fluid Flow

Decay of Temperature Fluctuations in Homogeneous Turbulence before the Final Period. A. L. Loeffler, Jr. and R. G. Deissler. *Inter. J. Heat Mass Transfer 1,* 4, 312 (1961) Jan. (13 pp.) [From *Appl. Mech. Rev. 14,* 719 (1961) Sept.]

A previous analysis of homogeneous turbulence for times before the final period has been extended to the case of temperature fluctuations in a homogeneous turbulence. The method consists essentially of the solution of the 2- and 3-point Fourier-transformed temperature equations after neglecting the fourth-order correlations in comparison with the second- and third-order correlations. Results are obtained for the convective transfer function, the spectral "energy" funtion and the total temperature fluctuation "energy." Comparison is made between the analysis and published experimental data obtained using air.

Entrainment in the Turbulent Boundary Layer. M. R. Head. *Aero Res. Counc. Lond. Rep. Mem. 3152* (1960) (17 pp.) [From *Appl. Mech. Rev. 14,* 717 (1961) Sept.]

Paper is based on the assumption that the rate of entrainment of fluid from outside into a turbulent boundary layer is a function of the shape of the velocity profile, the external velocity, and the boundary-layer thickness, and is independent of the Reynolds number.

J. C. Cooke

Gas Dynamic Processes Involving Suspended Solids. S. L. Soo. *A.I.Ch.E. J. 7,* 384 (1961) Sept. (8 pp.)

Basic gas dynamic equations involving suspended solid particles were formulated. Considerations include momentum and heat transfer between the gaseous and solid phases. Significance of these contributions was illustrated with the case of expansion through a de Laval nozzle. Duct flow and normal shock problems were also discussed. The extent of earlier methods of approximation was pointed out.

Some Applications of Crocco's Integral for the Turbulent Boundary Layer. *Proc. Heat Trans. Fluid Mech. Inst.,* Stanford, California, June 15-17, 1960; Stanford Univ., 1960 (15 pp.) [From *Appl. Mech. Rev. 14,* 717 (1961) Sept.]

Based upon results of experiments which indicated that the velocity profile in a supersonic compressible boundary layer is nearly a "universal" function of the Howarth-Dorodnitzyn variable author evaluates a form of Crocco's integral for turbulent Prandtl numbers different from unity to obtain the associated shear stress distribution, enthalpy distribution, recovery factor, and heat transfer coefficient. The second half of the paper generalizes the Stewartson-Illingworth transformation for flow with heat transfer. Particular choices of wall temperature distribution are found to lead to integrable forms of the integral momentum equation in the Stewartson variables when the recovery factor is not unity. Expressions are found for skin friction and the growth of the momentum thickness in a favorable pressure gradient with various rates of wall cooling.

R. L. Curl.

Turbulent Flow Ballistics Facility for Particle Momentum Transfer Studies. L. B. Torobin and W. H. Gauvin. *A.I.Ch.E. J. 7,* 406 (1961) Sept. (5 pp.)

This paper describes the calibration and use of an experimental installation which was specifically designed for the quantitative measurement of the drag coefficient of single particles moving with a turbulent fluid. The installation consisted of an 8 in. I.D. wind tunnel with an 18 ft test section, preceded by an inlet grid arrangement designed to provide a flow with a symmetrical mean velocity profile and a flat central core having a nonperiodic spectrum of turbulence. The particles were launched at controlled entrance velocities into the core

in a nonrotating manner by means of a particle accelerator, and axial motion was obtained. A hot wire anemometer was used to measure the flow turbulence parameters at 2 Reynolds numbers by means of probes inserted at various distances above the inlet grid section.

Heat Transfer

A Finite-Difference Method of High-Order Accuracy for the Solution of Three-Dimensional Transient Heat Conduction Problems. P. L. T. Brian. *A.I.Ch.E. J. 7,* 367 (1961) Sept. (4 pp.)

A finite difference method is presented for solving 3 dimensional transient heat problems. The method is a modification of the Douglas and Rachford which achieves the higher-order accuracy of a Crank-Nicholson formulation while preserving the advantages of the Douglas-Rachford method: unconditional stability and simplicity of solving the equations at each time level. Although the method has not yet been applied, the analysis in this paper suggests that it will prove to be the most efficient method yet proposed for the numerical integration of three dimensional transient heat conduction problems.

Derive Your Own Transport Equations. L. D. Smoot. *Chem. Eng. 68,* 183 (1961) Sept. 18 (4 pp.)

This article shows the derivation of the general equations of change of mass, heat, and momentum, and presents these equations in various coordinate systems for later use. Since the derivation of one is much like that of another, only the equation of conservation of mass is fully developed. The conservation of energy and of momentum equations are shown in tables in the article.

The Specific Heat at Constant Volume, the Entropy, the Internal Energy, and the Free Energy of Liquid Helium-4 Between 1.2 and 2.9°K. O. V. Lounsmaa. *Cryogenics 1,* 212 (1961) June (10 pp.)

Tables of specific heat at constant volume (from 1.2 to 2.9°K), the entropy, and the internal energy (both from 1.5 to 2.9°K) of liquid helium-4 between the solidification and vaporization curves are published, together with diagrams of these functions and of the free energy. The results are based on new measurements of the equation of state (p and $(\partial p/\partial T)_V$) near 1.75°K, on specific heat data by Lounsmaa and Kojo.

Helium

Compressibility Factors for Helium and Helium-Nitrogen Mixtures. J. E. Miller, L. W. Brandt, and L. Stroud. *U. S. Bur. Mines Rep. Invest. 5845* (Washington, D.C. U. S. Govt. Print. Off., 1961)

This paper reports experimental determinations by the Bureau of Mines of compressibility factors to 4,000 psia for helium at temperatures from −10° to 130°F and for 16 helium nitrogen mixtures at 70°F. This information is needed for computing accurate discharge volumes and is necessary for determining an average-density value for use in orifice-meter formulas. In thermodynamic calculations, several functions of the compressibility factor with pressure and temperature are required.

Kinetics

Kinetics of the Ethylene Hydrogenation on Evaporated Nickel and Iron Films. K. J. Laidler and R. E. Townshend. *Trans. Faraday Soc. 57,* 1590 (1961) Sept. (13 pp.)

The kinetics of the reaction between ethylene and hydrogen have been studied over a range of temperatures (30-80°C) and of pressures of ethylene and hydrogen (10-300mm). The order of introduction of gases was found to be important, the relative rates being: hydrogen first > simultaneous > ethylene first. Initial rates were approximately first-order in hydrogen and of negative order in ethylene; the activation energy with nickel was 7.8 kcal for simultaneous introduction of gases, and 10.0 kcal when the ethylene was added first. These results together with the analysis of the time course of the reaction under a variety of conditions lead to the conclusion that two mechanisms are involved: a Langmuir-Hinshelwood reaction between adsorbed ethylene and hydrogen molecules; and a Rideal reaction between adsorbed hydrogen and gaseous ethylene.

Mass Transfer

Mass Transfer in the Flow of Gases Through Fluidized Beds. R. E. Riccetti and G. Thodos. *A.I.Ch.E. J. 7,* 442 (1961) Sept. (3 pp.)

Mass transfer studies were conducted for the flow of air through fluidized beds. These studies were concerned with the sublimation of a p-dichlorobenzene spherical particles, approximately 0.04 to 0.08 in. in diameter and with the evaporation of nitrobenzene and water from alumina spheres 0.1168 in. in diameter. Void volumes for these fluidized beds were calculated from pressure drop measurements. The results of this investigation were used to establish mass transfer factors which were in agreement with values obtained for fixed beds for corresponding modified Reynolds numbers, $D_pG/\mu(1-\epsilon)$.

Methane

Kinetics of Carbon Deposition in a Fluidized Bed. J. H. Oxley, A. C. Secrest, N. D. Veigel, and J. M. Blocher, Jr. *A.I.Ch.E. J. 7,* 498 (1961) Sept. (4 pp.)

Rate data have been obtained for the deposition of carbon films from methane and acetylene in fluidized beds of alumina, uranium dioxide, uranium monocarbide, and a solid solution of uranium-thorium dicarbide powders. These carbon films have been shown to provide excellent protection for the powdered fertile material against attack by hot concentrated nitric acid solutions. The coated uranium-thorium dicarbide particles were also shown to be stable in humid air.

Phase Equilibria

An Equation for the Liquid and Vapor States of Nitrogen. R. F. Bukacek and R. E. Peck. *A.I.Ch.E. J. 7,* 453 (1961) Sept. (3 pp.)

An equation of state which describes vapor and liquid states of nitrogen in the temperature and density range to 3 times the critical and the 2-phase boundary is

presented. The root mean square error is less than 0.7% in describing the available data for nitrogen. The equation contains 13 coefficients, only 3 or 4 of which are independent, and can be written in virial form.

Heterogeneous Phase and Volumetric Behavior of the Methane-n-Heptane System at Low Temperature. J. P. Kohn. *A.I.Ch.E. J. 7,* 514 (1961) Sept. (5 pp.)

The phase behavior of the methane-*n*-heptane system was determined at temperatures from −200° to 340°F at pressures up to 1,500 psia. The system was found to have a miscibility gap in the liquid-vapor region. The compositions of phases along the three phase (L_1—L_2—V) locus indicate that the L_1 phase is approximately 0.64 mole fraction methane and that the L_2 and V phases are substantially pure methane phases. The quadruple point (L_1—L_2—S_1—V) was found at a temperature of −154.4°F and a pressure of 339 psia; a singular point (type *k*) at which the L_2 phase was found at −114.6°F and at a pressure of 694 psia.

Liquid-Vapor Equilibria in the Hydrogen-Nitrogen and Deuterium-Nitrogen Systems. A. Maimoni. *A.I.Ch.E. J. 7,* 371 (1961) Sept. (5 pp.)

A recirculation type of apparatus with a novel liquid-sampling system was used to obtain liquid-vapor equilibrium data for the hydrogen-nitrogen and deuterium-nitrogen systems at 90° and 95°K and pressures up to 1000 psia. The data obtained show an average scatter in liquid compositions of the order of 0.01%, thus proving the feasibility of the new liquid sampling system. The vapor samples are shown by thermodynamic analyses to scatter less than 0.1%. Deuterium is slightly more soluble in liquid nitrogen than hydrogen.

Polymeric Membrane

Inorganic Membrane Works in Fuel Cells. *Chem. Eng. News 39,* 40 (1961) Oct. 16.

Polymeric $ZrO(H_2PO_4)_2$ may lead to more efficient fuel cells, and allow high temperature operation. A workable inorganic membrane for the hydrogen-oxygen or the hydrogen-air fuel cell has been developed. An inorganic membrane can operate at 100°C or higher, and it permits operation at current densities much higher than now possible with organics. In operation, this cell acts as any other membrane cell. Hydrogen donates an electron as it ionizes at the anode screen, catalyzed by the underlying platinum black catalyst. Then hydrated by one or more molecules of water, the hydrogen ion diffuses into the porous ion transport membrane and skips across available proton sites on the phosphate groups. When the hydrogen ion emerges at the cathode, it picks up an electron, combines with another proton and oxygen to form water.

Polymers—Inorganic

Hydrous Ferric Oxide May Be a Polymer. *Chem. Eng. News 39,* 42 (1961) Sept. 25.

Study of ionic species that lead to gel formation points to a monomer linked to a hydrated dimer. A polymeric structure for hydrous ferric oxide has been proposed. The polymer is made up of hydrated iron (III) monomer linked to hydroxyl or oxo bridges to a hydrated dimer, $(Fe(OH)_2Fe)^{4+}$, plus possibly some trimer and tetramer. Customarily the hydrated oxide is called a gel. It exists as a colloid or solid, and all data point to a polymer of iron (III). Dehydration isotherms yield information on composition; surface area studies show small particles; and large areas explain catalytic activity associated with the structure. X-ray and electron diffraction give diffuse patterns, suggest structural relationships only vaguely. Measurements of magnetic moment of the gel, however, are consistently much lower than measurements made on typical iron (III) salts.

Raw Materials Development

Coal Holds Jet Fuel Raw Material Potential. *Chem. Eng. News 39,* 56 (1961) Oct. 23 (2 pp.)

French develop process to make high energy jet fuels from tar fraction; its success could aid world coal industry. New high energy fuels have been made from a coal tar fraction high in polycyclic aromatics. The process turns out a fuel with a high density, high heat of combustion, low freezing point, and high hydrogen content. These, plus other properties, make it potentially better fuel for supersonic jet planes than those now in use.

Thermocouples

Low Temperature Thermocouples—I. Gold-Cobalt or Constantan Versus Copper or "Normal" Silver. R. L. Powell, M. D. Bunch and R. J. Corruccini. *Cryogenics 1,* 139 (1961) Mar. (12 pp.)

An apparatus for calibrating thermocouples from 4 to 300°K is described. It has been used to obtain a detailed calibration table of the thermoelectric power and potential difference for constantan, gold-cobalt (gold—2.1 atomic percent cobalt), and "normal" silver (silver—0.37 atomic percent gold) versus copper. At low temperatures gold-cobalt versus copper (respectively 16 and 6 μV/°K at 20°K). Unfortunately, however, it is also more inhomogenous, so that uncertainties in temperature measurement are approximately the same. The 'normal' silver is thermoelectrically very similar to "normal" silver is thermoelectrically very similar to copper. Results are included of inhomogeneity, annealing, and long time stability tests.

Thermodynamics

The Theory of Combined Steam and Gas Turbine Installations. C. Seippel and R. Bereuter. *Combustion 33,* 30 (1961) Sept. (12 pp.)

This article gives a comprehensive and unbiased survey of the combinations worth considering and derives the basic thermodynamic relationships, which determine their mode of operation. These relationships, though simple, have not always been correctly analyzed.

Thermodynamic Properties of Sulfur Dioxide. T. L. Kang and J. J. McKetta. *A.I.Ch.E. J. 7,* 418 (1961) Sept. (5 pp.)

With the widespread use of the digital computers thermodynamic properties of a substance can be evaluated directly from its pressure-volume-temperature relationships without recourse to the specific equation of a state of that substance. Based on the experimental P-V-T data and in conjunction with other data in the literature, the thermodynamic properties of SO_2 were evaluated from −100° to 480°F for pressures up to 4,600 psia. Numerical methods were employed, and an IBM-650 digital computer was used to carry out the calculations.

Ultraflotation

Ultraflotation Gets First Commercial Try. *Chem. Eng. News 39,* 52 (1961) Oct. 16 (3 pp.)

Ultraflotation processing for up grading minerals and ores goes beyond conventional flotation, and makes the technique usable for submicron particles. An auxiliary mineral is used which seems to act as a carrier for floatable particles. The floatable particles ride out in piggyback style on the carrier grains. The carrier grains are in turn hooked to the air bubbles. In conventional flotation, air bubbles alone do the job. Conventional flotation has thus been generally limited to ores having an average particle size of 50 microns or more. Ores that are naturally slimed, or that slime on grinding, as well as other material of very fine particle size, can be upgraded by flotation. Originally developed to improve kaolin clays by floating out titaniferous impurities ultraflotation is visualized as having a definite potential in other types of preparations.

Ultrasonics

The Sonochemical Reactions of Carbon Tetrachloride and Chloroform in Aqueous Suspension in an Inert Atmosphere. B. H. Jennings and S. N. Townsend. *J. Phys. Chem. 65,* 1574 (1961) Sept. (6 pp.)

The sonochemical reactions of CCl_4—H_20 mixtures in an argon atmosphere have been investigated and compared with those of $HCCl_3$—H_2O mixtures. The observed products from the CCl_4 reaction were CO_2, O_2, Cl_2, HCl, C_2Cl_6, and C_2Cl_4. After an initiation period, the rates of formation of certain products were found to be constant: $d(Cl)/dt = 9.6$ μequiv./min; $d(C_2Cl_6)/dt = 4.2$ μmoles/ min. (20°); the rate of production of C_2Cl_4 was an order of magnitude slower; the elemental Cl_2 concentration remained essentially constant after the first half hour of reaction. After the initial period the rate of production of inorganic chlorine was insensitive to a 15° temperature change. The products identified from the $HCCl_3$ reaction were HCl, C_2Cl_6, and C_2Cl_4: $d(Cl)/dt = 4.1$ μequiv./min. (20°). Some interrelationships between cavitation and chemical reaction are discussed. A free radical mechanism is proposed to account for the rate data and observed products.

Ultrasonics in Processing. R. M. G. Boucher. *Chem. Eng. 68,* 83 (1961) Oct. 2 (18 pp.)

Sonics and ultrasonics already offer practical advantages in drying heat-sensitive powders and fibers, in various types of gas-cleaning equipment, and in controlling foams. If improvements in sonic generators materialize, the gas precipitation plants may stage a comeback. In Japan, 2 industrial plants installed in 1952 for tar removal in the gas industry, have been in use 8 years, and are quite efficient. Each ultrasonic precipitator handles 212,000 cf/hr in a vertical countercurrent tower 33 ft high with a 3½ ft diameter. Contact time inside the agglomeration tower is 6 sec. The final collector is a drum type impinger. Tar mist loading has ranged between 6 and 15 g/cu. m. The sound source is a rotary siren with a 35% over-all efficiency.

Vacuum Tubes

New Look at Vacuum Tubes. L. Noble and R. K. Waits. *CEC Recordings 15,* 20 (1961) 3rd Quarter (2 pp.)

One of the most frequent causes of failure in high vacuum tubes is the presence of residual gases. When an excessive amount of residual gas builds up inside the tube it becomes ionized, collects on the electrodes, and finally neutralizes the applied field within the tube. Efforts to develop manufacturing techniques to overcome this problem in the past have been severely limited by the lack of proper measuring instruments. However, with the development of the mass spectrometer residual gas analyzer it is possible to determine the composition of residual gases under actual operating conditions. Hydrogen, water, carbon monoxide, carbon dioxide, and methane were found to predominate during a 12 hr 500°C bakeout period. It is believed that the hydrogen, carbon monoxide, and methane originated from the ceramic and metal tube parts. The carbon dioxide and some carbon monoxide may have been formed by partial decomposition of the cathode.

Vapor Pressure

Vapor Pressures of the Inert Gases. C. E. Hamrin, Jr. and G. Thodos. *J. Chem. Phys. 35,* 899 (1961) Sept. (4 pp.)

A single vapor-pressure relationship applicable from the triple point to the critical point has been found to exist for the inert gases argon, krypton, and xenon when the reduced vapor pressure P_R is related to T_R the reduced temperature. This vapor pressure function results from the Frost-Kalkwarf equation. The reduced vapor-pressure data for helium and neon produced similar reduced vapor-pressure relationships having different constants. These results are not unexpected in view of the significant quantum effects associated with helium and to a lesser degree with neon.

Water

Flash Distillation Plants. W. Smith. *Chem. & Process Eng. 42,* 391 (1961) Sept. (4 pp.)

The importance of distillation as a means of producing fresh water from sea-water has been of particular importance to the oil industry—since wells are often situated in arid zones. A particularly efficient method of distilling sea-water is to heat it and then pass it through a series of chambers each at reduced pressure

so that a quantity of steam is flashed off in each chamber. This article describes the engineering and operation of both a very large and a small package flash distillation unit.

Fresh Water from Saline Sources. T. I. Hudson. *Chem. & Process Eng. 42,* 387 (1961) Sept. (4 pp.)

The uneven distribution of rainfall throughout the world has created many regions which suffer from an extreme shortage of water, both for drinking and industrial purposes. During the last decade many methods have been economically developed for reclaiming fresh water from brackish or saline sources. This article surveys such existing methods, which comprise mainly chemical reaction processes, electrodialysis, and distillation. The suitability of each method for a particular application is discussed.

Principles of Low-Pressure Flash Evaporators. W. Steiner. *Chem. & Process Eng. 42,* 395 (1961) Sept. (7 pp.)

A very large flash evaporation plant is currently being designed and constructed for desalination. Fundamental principles of flash evaporation are discussed in this article, which first analyzes conditions obtained in a single flash chamber. The thermodynamics of evaporators are then discussed and various economic evaporation cycles are propounded. Finally, various problems facing designers such as feed water treatment, scale, and corrosion prevention are stated.

Wells—Geothermal

Drilling Steam Wells. A. Langton. *Petrol. Eng. 33,* 43 (1961) Oct. (10 pp.)

Geothermal heat to be of economic value, must be contained in gases or fluids as mobile carriers. If contained in gases, such gases must be under pressure sufficient to produce from wells and transmit to engines with adequate remaining pressure to drive the engines. If contained in water the temperature must be sufficiently high to flash off steam or permit heat transfer to some other media more adaptable for driving engines. The hydrostatic head of a column of hot water, as with any fluid, increases with depth, with a corresponding increase in the boiling point. At 1,000 ft the boiling point would be 215°C (419°F) compared to 100°C (212°F) at sea level. A shaft, such as a geothermal prospect, drilled into a formation carrying water at a sufficiently elevated temperature would release the pressure on the fluid enough to cause it to flash into steam as it escaped through the shaft.

X-Y Pulsed Measuring System

The Application of an X-Y Pulsed Measuring System to Polarization Studies. I. The Hydrogen Reaction on Platinum. C. H. Presbrey, Jr. and S. Schuldiner. *J. Electrochem. Soc. 108,* 985 (1961) Oct. (11 pp.)

The X-Y pulsed measuring system developed at the Naval Research Laboratory by Haas and Harris was modified and used in the study of electrochemical systems. By means of a versatile pulse generator and a modified double sweep oscilloscope, a highly flexible system giving accurate control of pulse rise time, repetition rate, length, amplitude, and delay makes it possible to determine the electrokinetic parameters of fast reaction steps. An investigation of the hydrogen reaction on platinum in acid solution resulted in a quantitative separation and determination of solution resistance, charge on the double layer, and the discharge/ionization reaction step. When a constant-current pulse is applied to a platinum electrode in a hydrogen-saturated acid solution several events occur. If the rates of these events are different enough and the measuring resolution is adequate, the effect of each event can be separated during the transient period.

Services Available to GAS ABSTRACTS Readers

Photocopies

Photocopies of all articles abstracted in *Gas Abstracts*, except those enumerated here, are available from the Institute at cost:*

1) Russian Articles.—Abstracts are obtained from services specializing in this field. English translations can be supplied by arrangement with the appropriate abstractor.
2) U.S. Patents.—Printed copies can be secured at 25 cents each (remittance with order) from the Commissioner of Patents, Washington 25, D.C.
3) Books, Special Reports.—When a price is given in the abstract, these should be secured from a bookdealer or the publisher; when stated *free*, from the publisher.

Types of Photocopies

Depending on the "tightness" of the binding (which determines whether pages can be laid flat without breaking the binding), and the color of the paper and ink used in the original being copied, photocopies may take any of several forms:

1. Positive paper prints made by the reflex process.
2. Positive paper prints enlarged by xerography from microfilm negatives.
3. Negative photostats.
4. Positive photostats.

Choice of the method used must necessarily rest with the Institute. All photocopies are approximately the same size as the original material.

Cost of Service

The photocopy service charge is:

First 5 pages or fraction thereof of one article in one issue $1.50

Each subsequent 4 pages or fraction thereof of the above one article in the same issue.....$1.00

Invoices are rendered to the Institute's Members and Contributors only; payment in advance is required of others.

The Institute may, at its option, fill orders from non-Members and non-Contributors without payment in advance, but an additional charge of $1.00 to cover billing costs will be made on each such order.

Microfilm

Microfilm copies of articles abstracted in *Gas Abstracts* are likewise available at cost.* The material is photographed on 35 mm unperforated negative film at 5¢ per page, with a minimum of 50 pages, $2.50, per order. Invoices are rendered to the Institute's Members and Contributors only; payment in advance is required of others.

The Institute may, at its option, fill orders from non-Members and non-Contributors without payment in advance, but an additional charge of $1.00 to cover billing costs will be made on each such order.

Bibliographies and Literature Searches

The library will prepare bibliographies and make literature searches on a cost basis plus a service charge. A comprehensive statement detailing the problem must be presented with the request.

Gas Abstracts on Cards

The abstracts in each monthly issue are also printed individually on 5 x 8-inch cards. Each card bears at its top the author and subject headings under which it may be filed. As many copies of each card are supplied as there are headings on that card, enabling filing of the abstract under all of its headings, eliminating cross-indexing.

The annual subscription to *Gas Abstracts on Cards*, a mailing of 500-1000 cards each month, is $120.00 to U. S. addresses, $150.00 foreign.

Since the printing order for cards is based on the current number of subscribers, a subscription for this service commences with the month in which the order is received. Back numbers of *Gas Abstracts on Cards* are not available.

Back Numbers of Gas Abstracts

In response to an increasing number of requests from utilities, colleges, and technical libraries which have only recently learned of the reference value of *Gas Abstracts*, the Institute has taken steps to make available single numbers, volumes, or complete files of this publication to date, starting with Vols. 1 (1945) and 2 (1946), some numbers of which are out of print.

The latter numbers are reproduced by a photoprinting process from copies in the Institute's libraries, and Vols. 1 and 2 can now be purchased at $35 per volume, unbound; single monthly numbers are offered at $3 each.

Vols. 3 to date are available at current subscription prices, $18 per volume to U. S. addresses, $22 foreign. Monthly numbers are $2 each.

---

*In requesting and accepting photocopies or microfilm copies, the applicant agrees to the following:

1. The applicant desires this duplication solely for use in lieu of loan or manual transcription. Responsibility for questions of copyright that might arise in this copying, and in the use of the copies, is assumed by the applicant.

2. The applicant understands that the Institute does not sell the photocopies, but merely performs the service of copying at the applicant's request; the fee paid is exclusively for such service and is established on the basis of no profit to the Institute.

3. The Institute reserves the right at its own discretion to decline to make photocopies requested, or to limit the number of copies, within the principle of fair use of copyrighted material.

Publications Abstracted for GAS ABSTRACTS

Air Conditioning, Heating and Ventilating
Air Engineering
Air Pollution Control Association, Journal of
American Chemical Society, Journal of
American Gas Association Monthly
American Gas Journal
American Institute of Chemical Engineers, Journal of
American Society of Mechanical Engineers, Transactions of
Engineering for Power, Journal of (Series A)
Engineering for Industry, Journal of (Series B)
Heat Transfer, Journal of (Series C)
Basic Engineering, Journal of (Series D)
Applied Mechanics, Journal of (Series E)
Analytical Chemistry
Appliance Manufacturer
Applied Chemistry, Journal of
Applied Mechanics Reviews
Applied Physics, Journal of
Applied Spectroscopy
ARS Journal
ASHRAE J.
Australian Journal of Applied Science
Australian Journal of Chemistry

Battelle Technical Review
Bituminous Coal Research
Brennstoff-Chemie (German)
British Coal Utilization Research Association Monthly Bulletin and *Quarterly Gazette*
Business Week
Butane-Propane News

Canadian Chemical Processing
Canadian Gas Journal
Canadian Journal of Chemical Engineering
Canadian Journal of Chemistry
Canadian Journal of Physics
Ceramics (British)
Chemical and Engineering Data, Journal of
Chemical and Engineering News
Chemical & Process Engineering
Chemical Documentation, Journal of
Chemical Education, Journal of
Chemical Engineering
Chemical Engineering Progress
Chemical Physics, Journal of
Chemical Processing
Chemical Reviews
Chemical Society, Journal of (British)
Chemical Society, Proceedings (British)
Chemical Week
Chemistry & Industry (British)
Chromatography, Journal of (Netherlands)
Coal-Heat
Coal Utilization
Coke and Gas (British)
Combustion
Combustion and Flame (British)
Compressed Air
Computers and Automation
Control Engineering
Corrosion
Corrosion Technology (British)
Cost Engineering
Cryogenics

Datamation
Design News
Drilling

Electrochemical Society, Journal of
Electronics
Engineers' Digest (British)
Erdöl und Kohle (German)

Faraday Society, Transactions of (British)
Fuel (British)
Fuel Efficiency (British)
Fueloil & Oil Heat

Gas
Gas Age
Gas Council Research Communications (British)
Gas Heat and Comfort Cooling
Gas Industries
Gas Journal (British)
Gas Service and Domestic Coke
Gas Times (British)
Gas- und Wasserfach (German)
Gas World (British)
Gazovaya Promyshlennost (Russian)

Heating, Piping & Air Conditioning

Independent Petroleum Monthly
Industrial and Engineering Chemistry
Industrial Finishing (British)
Industrial Gas (American)
Industrial Gas (British)
Industrial Heating
Industrial Research
Industries du Gaz, Journal des (French)
Institute of Fuel, Journal of (British)
Institute of Gas Technology Research Bulletins
Institute of Petroleum, Journal of (British)
Institution of Gas Engineers Journal (British)
Instrumentation
Instruments and Control Systems
Izvestiva Akademii Nauk S. S. S. R. Otdelenie Khimicheskikh Nauk (Russian)

Khimiya i Tekhnologiya Topliva i Masel (Russian)

LP-Gas

Materials Research & Standards
Mechanical Engineering
Mechanical Power (British)
Metals, Journal of

National Aeronautics and Space Administration Memorandum
National Fire Protection Association Quarterly
National Gas Bulletin of Australia
National Petroleum News
Nuclear Science and Engineering
Nucleonics

Oil and Gas Journal
Organic Chemistry, Journal of

Petro/Chem Engineer
Petroleum (British)
Petroleum Engineer, The (Drilling and Producing)
Petroleum Management
Petroleum Refiner
Petroleum Technology Journal of
Petroleum Times
Physical Chemistry, Journal of
Physics and Chemistry of Solids (British)
Physics of Fluids (British)
Pipeline Engineer
Pipe Line Industry
Pipeline News
Power
Producers Monthly
Product Engineering
Progress (Pakistan)
Public Utilities Fortnightly

Research/Development
Research, Journal of, A. Physics and Chemistry
Research, Journal of, B Mathematics and Mathematical Physics
Research, Journal of, C. Engineering and Instrumentation
Review of Scientific Instruments
Revue Generale du Gaz (Belgian)
Rivista dei Combustibili (Italian)

Science
Scientific & Industrial Research, Journal of, A. General (India)
Scientific & Industrial Research, Journal of, B. Physical Sciences (India)
Scientific Instruments, Journal of (British)
Society of Petroleum Engineers, Journal of
Stroitel'stvo Truboprovodov (Russian)
Svenska Gasverksföreningens Månadsblad (Swedish)

Technical News Bulletin

U.S. Bureau of Mines Bulletins, Information Circulars and *Reports of Investigations*
U.S. Patents
Uspekhi Khimii (Russian)

World Oil
World Petroleum